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Research and Development
Service
Washington, DC 20591

Safe Heliports Through Design and Planning

A Summary of FAA Research and Development

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Washington, DC 20591

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Final Report

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U.S. Department of Transportation
Federal Aviation Administration

NOTICE

U.S. Department
of Transportation

**Federal Aviation
Administration**

800 Independence Ave . S W
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FEB 8 1994

Dear Colleague:

In the interest of information exchange we have assembled **FAA/RD-93/17, Safe Heliports Through Design and Planning.** During the last decade, the Federal Aviation Administration (FAA) has published several dozen research and development (R&D) reports dealing with the planning and design of landing sites for vertical flight aircraft. These landing sites include helipads at airports, heliports, helistops, vertiports, and unimproved sites. Vertical flight aircraft include helicopters, tiltrotor, and tiltwing.

These reports would make a stack that is several feet high. Airport, heliport, and vertiport planners and designers should be familiar with FAA R&D efforts in this area. We recognize, however, that many people do not have the time to read all of the published material. In addition, without a "road map" through all of this material, it may be difficult to see how multiple documents fit together to tell a coherent story on a particular subject of interest. With this in mind, the FAA has prepared this summary to assist you in becoming familiar with the results of these efforts.

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16. Abstract

During the last decade, the Federal Aviation Administration (FAA) has published several dozen research and development (R&D) reports dealing with the planning and design of landing sites for vertical flight aircraft. These landing sites include helipads at airports, heliports, helistops, vertiports, and unimproved sites. Vertical flight aircraft include helicopters, tiltrotor, and tiltwing.

These reports would make a stack that is several feet high. Airport, heliport, and vertiport planners and designers should be familiar with FAA R&D efforts in this area. We recognize, however, that many people do not have the time to read all of the published material. In addition, without a "road map" through all of this material, it may be difficult to see how multiple documents fit together to tell a coherent story on a particular subject of interest. With this in mind, the FAA has prepared this summary to assist you in becoming familiar with the results of these efforts.

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1.0 PURPOSE. During the last decade, the Federal Aviation Administration (FAA) has published several dozen research and development (R&D) reports dealing with the planning and design of landing sites for helicopters, tiltrotor, and other vertical flight aircraft. In addition, a number of R&D documents on these issues are currently in process. Assembled in one spot, these reports would make a stack that is several feet high.

Airport/heliport/vertiport planners and designers should be familiar with FAA R&D efforts in this area. We recognize, however, that many people do not have the time to read all of the published material. In addition, without a "road map" through all of this material, it may be difficult to see how the multiple documents fit together to tell a coherent story on a particular subject of interest. With this in mind, the FAA has prepared this summary to assist you in becoming familiar with FAA rotorcraft R&D efforts.

With many of the reports discussed in this summary document, the overriding concern is safety. How safe must vertical flight operations be? Society in the USA has a two part answer:

(1) As safe or safer than comparable segments of aviation conducting similar missions, and

(2) Safer with each passing year. (See section 6.0 and Appendix A for additional discussion on this point.)

In all facets of aviation, accident analysis shows that takeoffs and landings pose a higher risk than en route flight. This is also true for rotorcraft operations. Clearly, if the rotorcraft community is to continue to reduce its accident rates, reductions must be achieved in the number of accidents taking place at or near landing sites. Such reductions can be achieved through a combination of actions including training, design, operational procedures, etc. This summary document focuses heavily on what should be done via changes in landing site design.

1.1 Scope and Applicability. This document provides a summary of FAA technical reports dealing with vertical flight landing site design and planning issues. Of the reports that address design issues, the majority are applicable to visual flight rules (VFR) facilities. Instrument approach R&D is a major topic by itself. This topic is addressed by a number of the documents discussed in this bibliography. However, there is a stronger focus on VFR design issues than on instrument flight rules (IFR) design issues.

Results of these efforts apply to landing sites at a variety of locations including heliports, helistops, airports, vertiports, and vertistops. Some of the results are also applicable to unimproved sites. Of particular interest are the available airspace and cleared ground area.

Vertical flight aircraft require a certain minimum airspace and ground area to operate safely. At a permanent landing site, these issues are addressed during the design process. These issues should also be addressed in selecting a temporary landing site even if there is no need or intention to improve it.

In the Code of Federal Regulations (CFR) Title 14, Federal Aviation Regulation (FAR) Part 157 provides an exemption to the normal heliport notice requirements. Under this exemption, a helicopter can conduct hundreds of operations at an unimproved site without providing notice to the FAA. However, while notice may not be required, good judgment in selecting a landing site is always appropriate.

This technical report does not constitute an Federal Aviation Regulation nor does it serve as an FAA advisory circular.

1.2 **Report Structure**. Concerning vertical flight landing site design, some of the R&D issues have resulted in complex efforts involving multiple reports. In order to show how the various facets of these complex efforts fit together, these issues and the associated documents are summarized and discussed in section 2. Other vertical flight landing site design issues are less complicated. These are addressed on a report by report basis in sections 3 and 4. Section 3 contains a chronological listing of published FAA R&D reports dealing with landing site design issues and a short synopsis of each. Section 4 contains a similar list for FAA R&D reports in progress.

Published vertical flight landing site planning reports are addressed in section 5.

The structure of this document allows the reader to become familiar with R&D efforts on particular design issues in section 2. It also allows the reader to become familiar with one or more technical reports of specific interest in sections 3, 4 and 5. This structure was chosen because it lends itself to convenient use by readers with vastly different levels of interest. However, using this structure does result in some repetition between sections.

Section 6 contains a discussion from a general safety perspective. This discussion relies heavily on the remarks of Congressman Mineta made in a 1984 speech to the American Institute of Aeronautics and Astronautics. These remarks deal with the topic of aviation safety and are appropriate for consideration in the discussion of vertical flight landing site design issues. (Appendix A contains the full text of the Congressman's remarks.)

Section 7 provides a brief summary of the conclusions on a number of vertical flight landing site design issues. Section 8

provides an overall summary and perspective on landing site design.

In response to questions from industry, the FAA recently reexamined the issue of rotorcraft tip clearances as a function of rotor diameter during ground taxi and hover taxi operations. Results of this analysis are contained in section 2.2.4 and in Appendix B.

1.3 Availability of Documents. The technical reports listed in this bibliography are readily available from three sources:

a. **National Technical Information Service (NTIS).** Many of the technical reports listed in this bibliography are available through NTIS. These documents can be identified by the accession number given after the listing of the document in sections 3 and 5. (In the example below, the accession is shown in **bold**.)

> Example: FAA/RD-90/8, Analysis of Helicopter Mishaps At Heliports, Airports, and Unimproved Sites
> **(NTIS: AD-A231235)**

NTIS is located at 5285 Port Royal Road, Springfield, VA 22161. The NTIS telephone sales desk is available between 8:30 AM and 5:30 PM EST, telephone: (703) 487-4650. NTIS FAX telephone number: (703) 321-8547. NTIS telex number: 64617. In ordering a document from NTIS, the accession number should be used. The cost is dependent on the number of pages in the document. Documents are available from NTIS both in microfiche and paper copy. Generally, the paper copies are printed from microfiche. For additional information, write or call the telephone sales desk and ask for the NTIS Product and Services Catalog, PR-827/360.

b. **American Helicopter Society (AHS).** Copies of all of the published technical reports listed in this bibliography have been given to the AHS. Both AHS members and nonmembers may obtain copies of reports for a fee.

c. **Helicopter Association International (HAI).** Copies of all of the published technical reports listed in this bibliography have been given to the HAI. HAI members may obtain copies of reports for a fee.

2.0 VERTICAL FLIGHT LANDING SITE DESIGN ISSUES. This section contains a synopsis of recent R&D efforts involving the following complex heliport/vertiport design issues:

a. Minimum VFR Heliport/Vertiport Airspace

b. Parking and Maneuvering Areas

c. Rotorwash

d. Helicopter Accident/Incident Analyses

e. Heliport/Vertiport Marking

2.1 Minimum VFR Heliport/Vertiport Airspace. For VFR heliports, approach and departure surfaces are described in the 1994 FAA Advisory Circular 150/5390-2A, Heliport Design. (For VFR vertiports, approach and departure surfaces are described in the 1990 FAA Advisory Circular 150/5390-3, Vertiport Design.) Since the heliport approach and departure surfaces constitute the minimum required airspace for public heliports, they have been the subject of debate for many years. During the 1984-1988 revision of the 1977 Heliport Design Guide Advisory Circular 150/5390-1B, the level of debate intensified and the FAA initiated an R&D effort in response.

During the 1960's, 1970's and the early 1980's, most of the discussion on this topic was been based on subjective experience. In response to industry recommendations in the mid-1980's, the FAA began several efforts to examine this issue objectively. The first facet of this examination involved flight testing. The second facet involved the examination of flight manuals and certification data. The third facet involved an operational survey of industry pilots. The fourth facet of this effort involved accident analyses. For straight-in approaches and straight-out departures, each of these facets is discussed below in sections 2.1.1.1 through 2.1.1.4. For curved approaches and departures, several of these facets are discussed below in sections 2.1.2.1 through 2.1.2.3.

2.1.1 Straight VFR Approaches/Departures.

2.1.1.1 Flight Testing - Straight Approaches/Departures. Several years ago, the FAA started a flight measurement project to examine the issue of minimum required VFR heliport airspace from a perspective of pilot performance. Test data were collected objectively in a manner similar to what is done to define the minimum airspace required for a precision approach. Heliport approach and departure flight profiles were recorded using a variety of subject pilots flying three different helicopters: a Hughes OH-6, a Sikorsky S-76, and a Bell UH-1.

A total of 1217 data runs (approaches or departures) were completed. These included 239 runs with the OH-6, 468 runs with the S-76, and 510 runs with the UH-1.

On approaches, the safety pilot flew the helicopter using a ground survey point (on centerline, 4000 feet from the heliport) to set up the approach. The subject pilot took control of the aircraft at 500 feet AGL with the heliport in sight. On departures, the subject pilot flew the helicopter without any use of the ground survey point.

Position data were analyzed statistically to determine the mean, standard deviation, and six sigma isoprobability curves. (The six sigma isoprobability curves are based on an assumption of Gaussian distribution and the same "target level of safety" that has long been used for precision approaches by international agreement.) Results of this effort are documented in FAA report FAA/CT-TN87/40, Heliport Visual Approach and Departure Airspace Tests.

At the start of these tests, some FAA personnel had expected that the results might justify some modest reduction in the lateral dimension of the minimum required VFR heliport airspace. Instead of supporting this point of view, however, the test results pointed toward a need to increase the minimum airspace substantially, both in the vertical and lateral dimensions. This result led the FAA to reexamine two issues: the selection of the "target level of safety" and the assumption of a Gaussian distribution of the flight data.

Regarding the selection of a six sigma "target level of safety", the FAA studied this issue and documented the results in FAA/DS-88/12, Minimum Required Heliport Airspace Under Visual Flight Rules. (A six sigma target level of safety means that, as a design goal, there should be no more than one collision with an obstacle in 10^7 approaches.) The six sigma target level of safety (TLOS) was chosen by the ICAO Obstacle Clearance Panel in the mid 1970's. This TLOS for IFR approaches was based on 1960's and early 1970's accident rates of fixed-wing, air transport aircraft during precision approaches to runways. Both nationally and internationally, this target level of safety has long been used to define the airspace required for all precision approaches, ILS and MLS, to runways or heliports. However, in 1987, it was not clear whether this was the best choice for a target level of safety for VFR approaches of general aviation helicopters to heliports.

Using an approach similar to that of the ICAO Obstacle Clearance Panel (i.e., accident rate analysis), the FAA chose a TLOS for VFR heliport approaches and departures. Results are documented in FAA/RD-90/9, Analysis of Rotorcraft Accident Risk Exposure at Heliports and Airports. This TLOS is based on 1977-87 helicopter

approach and departure accident rates. By coincidence, this TLOS is not significantly different than 1 in 10^7. Indeed, the recommended TLOS of 0.8 in 10^7 is just slightly more demanding than the TLOS of 1 in 10^7 originally chosen by the ICAO.

Regarding the issue of Gaussian distribution, a detailed statistical analysis of the VFR heliport approach and departure data is documented in report FAA/CT-TN89/67, Analysis of Distributions of Visual Meteorological Conditions (VMC) Heliport Data. This lengthy analysis (1054 pages) shows that the data are not Gaussian distributed and that the lateral airspace required is slightly smaller than the previous analysis (FAA/CT-TN87/40) had indicated. However, the analysis of FAA/CT-TN89/67 still indicates that the lateral dimension of the minimum required heliport airspace would need to be substantially increased to reach the selected TLOS. In addition, in the vertical dimension, the absence of an adequate safety margin continues to be a serious FAA concern.

With regard to airspace consumption in the lateral plane, the results of FAA/CT-TN89/67 can be reduced to two figures (See figures 1 and 2 shown on the following pages). These figures show the six sigma distribution lateral limits for the originally assumed Gaussian distribution, the six sigma distribution lateral limits for the actual Beta/Gamma distribution, and the current lateral limits of the 8 to 1 approach/departure surface defined in the Code of Federal Regulations (CFR) Title 14, Federal Aviation Regulation (FAR) Part 77. (Larger copies of these figures are shown in Appendix C.) Results can be summarized as follows:

1. In many but not all cases, the lateral limits of the six sigma distribution for the actual Beta/Gamma distribution are narrower than the lateral limits of the six sigma distribution for the originally assumed Gaussian distribution. Even so, there is a need to expand significantly the width of the approach/departure surface.

2. During departures, pilots consumed significantly more airspace in the lateral dimension than during approaches. (This is due to the method used to set up the approaches. The subject pilots initiated each approach at an altitude of 500 feet **over a surveyed ground reference marker** with the heliport in sight. In contrast, during departures, the subject pilots made no use of the ground reference marking.) As a consequence, the departure data show the airspace consumed when VFR heliport operations are unconstrained. The approach data show the airspace consumed when VFR heliport operations are constrained.

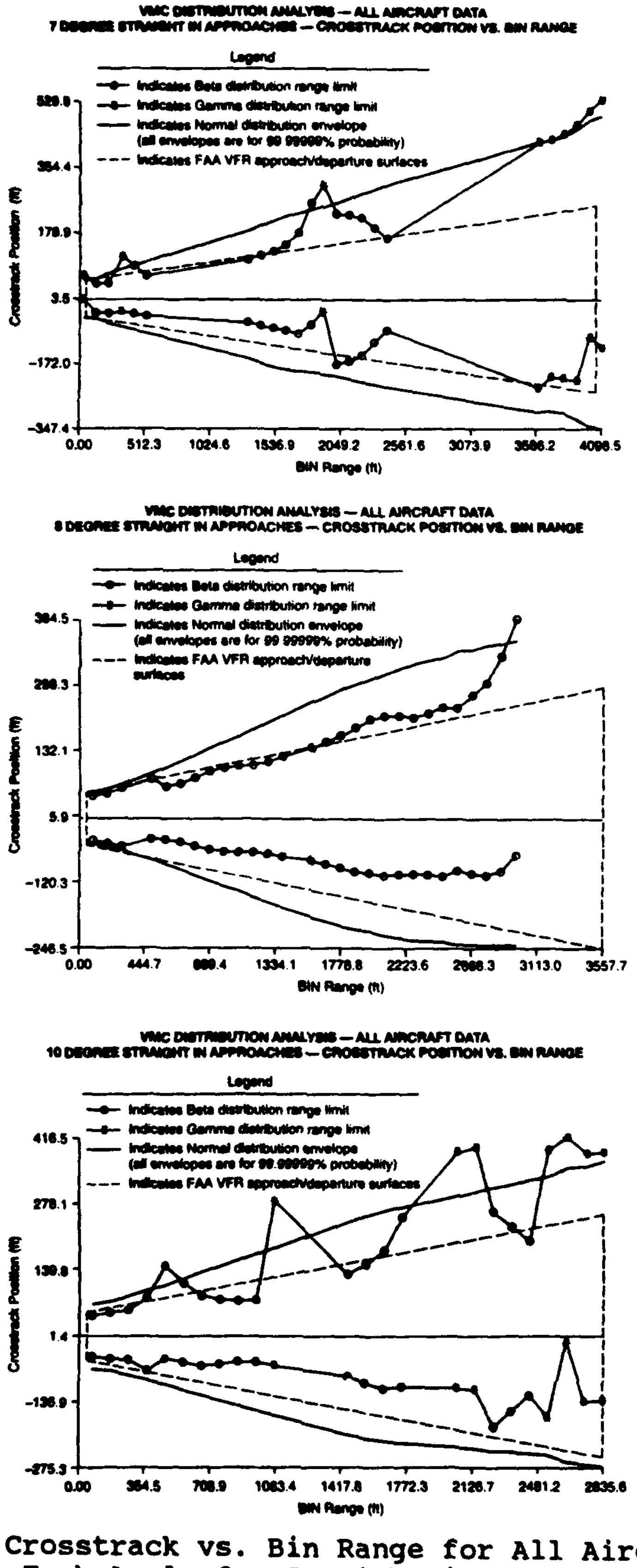


Figure 1. Crosstrack vs. Bin Range for All Aircraft Data for Each Angle for Straight-in Approaches

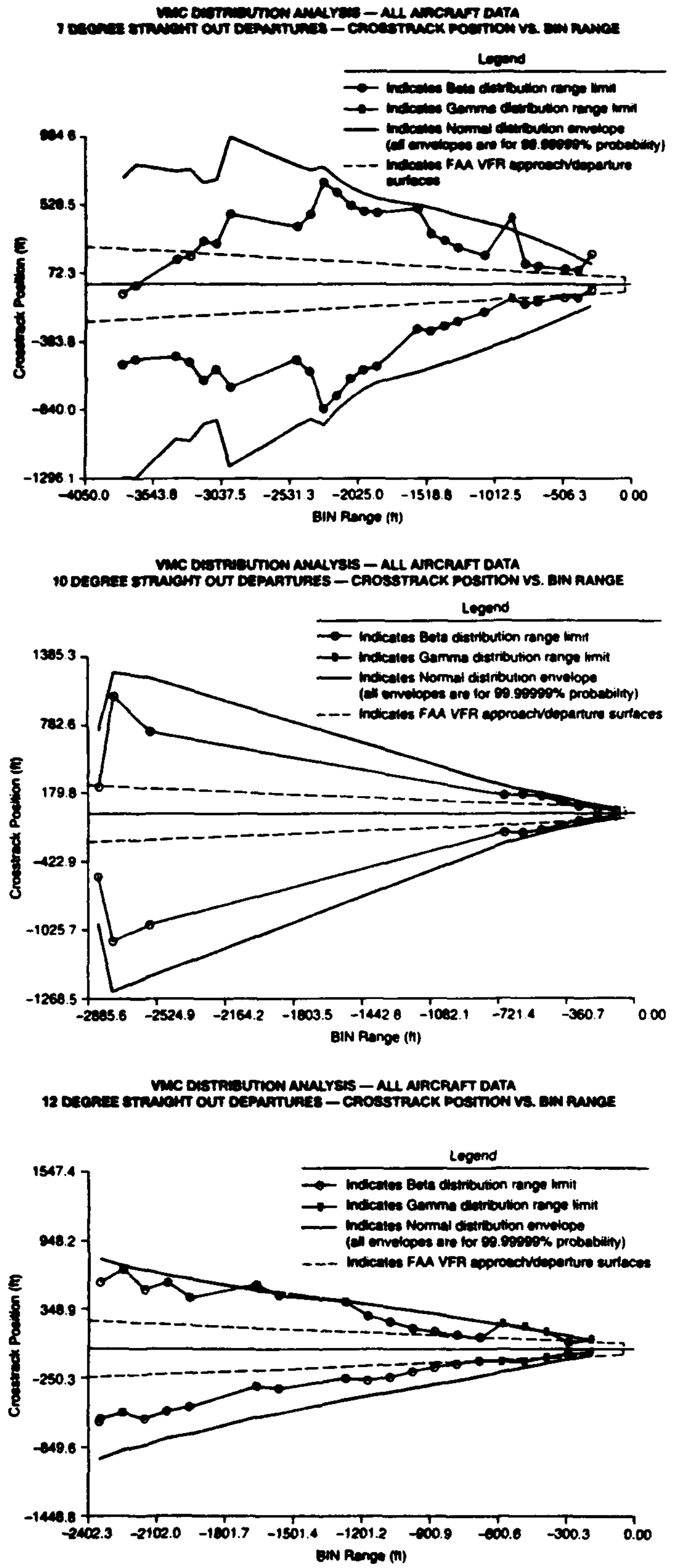


Figure 2. Crosstrack vs. Bin Range for All Aircraft Data for Each Angle for Straight-out Departures

3. Based on the plots of "All Aircraft Data" (See Figures 1 and 2), to achieve the recommended TLOS of 0.8 in 10^7 would require that the current lateral dimension of the approach/departure surface (currently 500 feet wide at a distance of 4000 feet from the edge of the heliport) be increased to the following amounts for the various cases:

7 degree straight-in approaches	1040 feet
8 degree straight-in approaches	1040 feet
10 degree straight-in approaches	1980 feet
7 degree straight-out departures	2424 feet
10 degree straight-out departures	4052 feet
12 degree straight-out departures	2878 feet

In the process of collecting approach and departure data, subject pilots were surveyed on their preferences for approach and departure angles. Pilots were also surveyed in an effort documented in "Operational Survey - VFR Heliport Approaches and Departures" (FAA/RD-90/5). With regard to approaches, pilots prefer an approach of approximately 7 or 8 degrees. The 10 degree approach was judged to be undesirable because it increased pilot workload and decreased the safety margin. For this and other reasons, we believe that a 10 degree VFR heliport approach will not be a common occurrence. Thus, we do not see a need to design all heliports for this event.

With regard to departures, pilot surveys indicate that pilots will fly a departure that is not much steeper than the minimum required by the obstacles in the vicinity. For this and other reasons, we believe that a 10 or 12 degree VFR heliport departure will not be a common occurrence. In addition, when these stepper departures are flown, the pilot will not maintain a 10 or 12 degree departure angle out to 4000 feet from the heliport. Thus, we do not see a need to design all heliports for this event.

With these thoughts in mind, only three of the six data points listed above are pertinent:

7 degree straight-in approaches	1040 feet
8 degree straight-in approaches	1040 feet
7 degree straight-out departures	2424 feet

With regard to the 7 degree straight-out departure, the FAA is mindful of the fact that this testing was conducted in an area with virtually no obstacles. This provided little in the way of a visual reference for the pilots during departure. (During the approach, the aircraft was positioned over a ground marker by the safety pilot and the subject pilots had the heliport itself as a visual reference.) Thus, these departure data are consistent with expected performance when a pilot conducts a nighttime departure from a heliport and the obstructions can not be seen.

This potential hazard could be alleviated by marking and lighting obstacles in the vicinity of the heliport and in the vicinity of the approach and departure paths (see figure 4).

Taking all of these issues into consideration, the heliport approach/departure airspace (for straight-in approaches and straight-out departures) can be designed safely based on the analysis of the airspace consumed during these 7 degree and 8 degree approaches. Thus, the current 500 foot dimension of the approach/departure path should be increased to 1040 feet. Corresponding changes should be made to the transition surfaces. Thus, the minimum required clear airspace is shown in figure 3. (This figure describes the clear airspace required for a landing site with only one approach and departure path.) In addition, within the adjacent airspace defined in figure 4, obstacles can safely be permitted if they are marked and lighted.

2.1.1.2 Analysis of Certification Data. Several years ago, the FAA started an examination of a selected number of helicopters from the perspective of performance capability. Results of this effort are documented in the following reports:

FAA/RD-90/3, Helicopter Physical and Performance Data

FAA/RD-90/4, Heliport VFR Airspace Based on Helicopter Performance

FAA/RD-90/6, Rotorcraft Acceleration and Climb Performance Model

The key report here is FAA/RD-90/4. (The other two reports are background documents.) Many of the conclusions and recommendations in this report are of great interest to members of the vertical flight community. In particular, we call your attention to the following conclusions:

a. Based on the helicopter performance profiles, the current VFR heliport protected airspace requirements are inadequate to cover the range of helicopters and operational conditions that are routinely encountered. The primary problems are the lack of an acceleration area adjacent to the helipad and the lack of a margin of safety between allowable obstructions and required helicopter performance.

b. Current civilian helicopter flight manuals do not contain sufficient performance data to adequately inform the pilot of aircraft confined area performance capability.

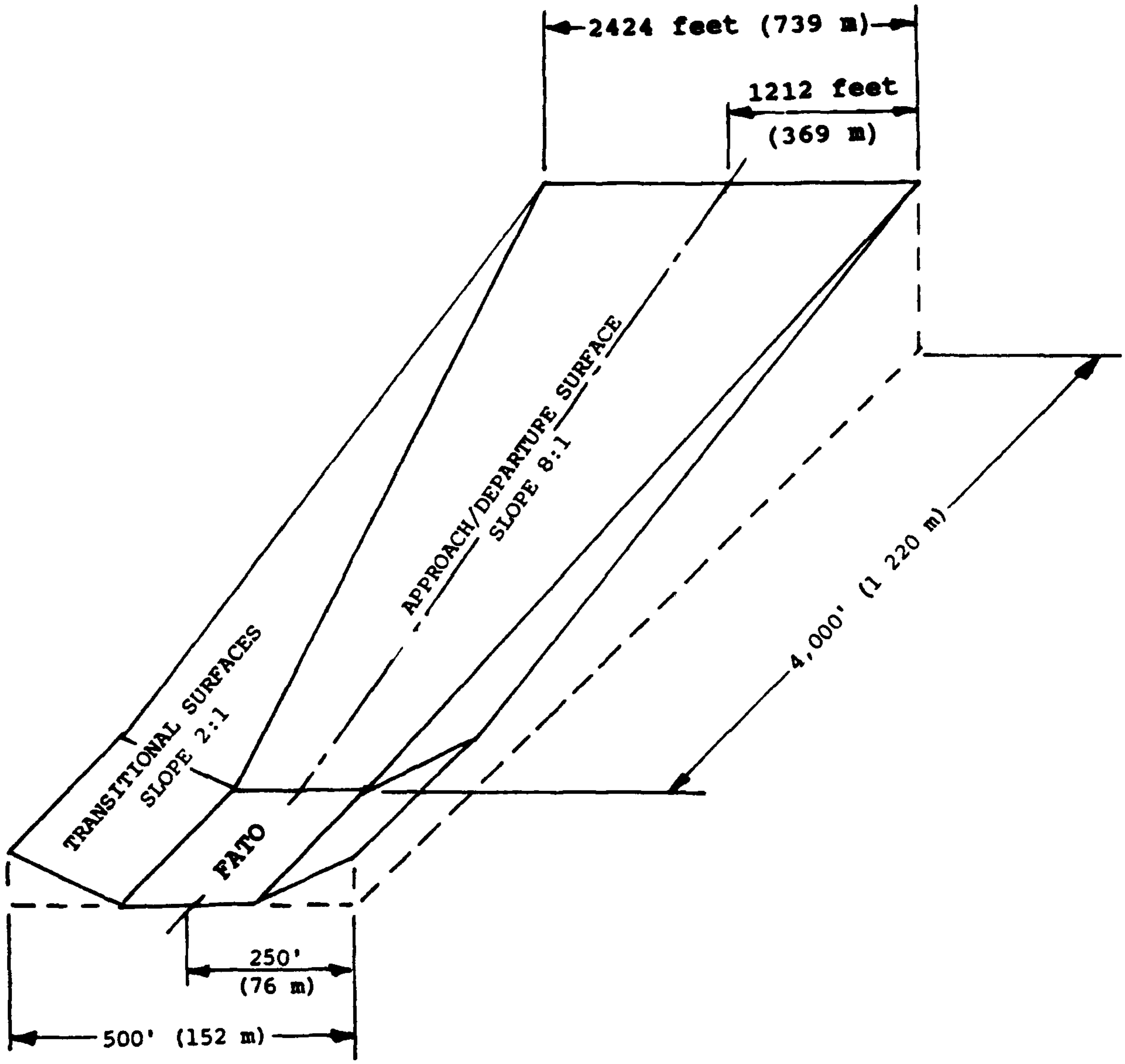


Figure 3. Minimum Required Airspace for Helicopter Landing Sites

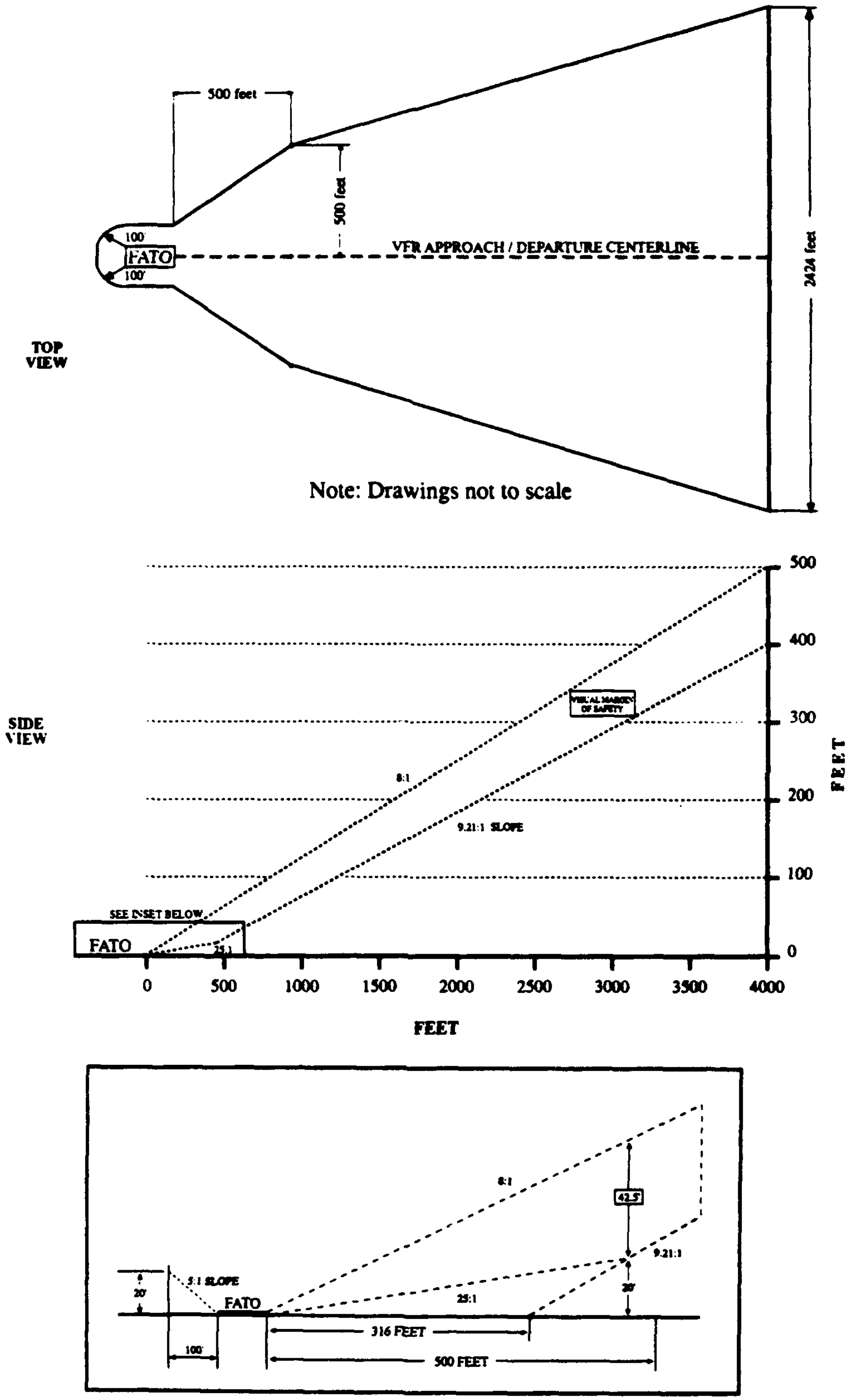


Figure 4. Airspace Where Marking and Lighting of Wires and Other Obstructions are Recommended

c. For four of the eight helicopters studied in report FAA/RD-90/3, the flight manual height-velocity curves (H-V diagrams) do not show operational advantages for reduced aircraft weight or low density altitude conditions. These maximum condition H-V diagrams tend to unnecessarily constrain pilots from achieving better helicopter performance in confined area operations.

These results indicate that, heliport design standards, vertiport design standards, and FAR 77 all need to be revised. The FAA should require an acceleration area prior to the start of the approach/departure surface. A minimum acceleration distance of 140 feet is required at sea level. Additional acceleration distance is needed at higher altitudes. With such an acceleration distance and a heliport field elevation of 3,000 feet or less, the current 8:1 approach/departure slope should be retained. For heliports with field elevations exceeding 3,000 feet, the approach/departure slope should be decreased to 9:1.

It should be recognized that the length of the FATO must be longer than the desired acceleration distance. As shown in figure 5, the length of the FATO includes the acceleration distance, the length of the helicopter, and the tip clearance required for the tail rotor. Taking all this into account, the minimum FATO recommended for public use heliports is shown in figure 6.

These conclusions were considered in the development of the 1994 Heliport Design AC. Some of these recommended changes are reflected in the chapter addressing transport heliports. A smaller number of these recommended changes are reflected in the chapter addressing public general aviation (GA) heliports.

We also call your attention to the following **long term recommendations:**

a. Flight Manuals - Performance Data - Require helicopter manufacturers to include necessary performance data in the helicopter flight manuals to inform the pilot of the aircraft's capabilities for operations at confined area heliports.

b. Flight Manuals - Height-Velocity (H-V) Diagrams - Require helicopter manufacturers to provide information in the helicopter flight manuals regarding the height-velocity curve that informs the pilot of the changing nature of this information as aircraft weight and density altitude change. (Currently, H-V diagrams are often overly conservative. However, this conservatism does not necessarily lead to safer rotorcraft operations.)

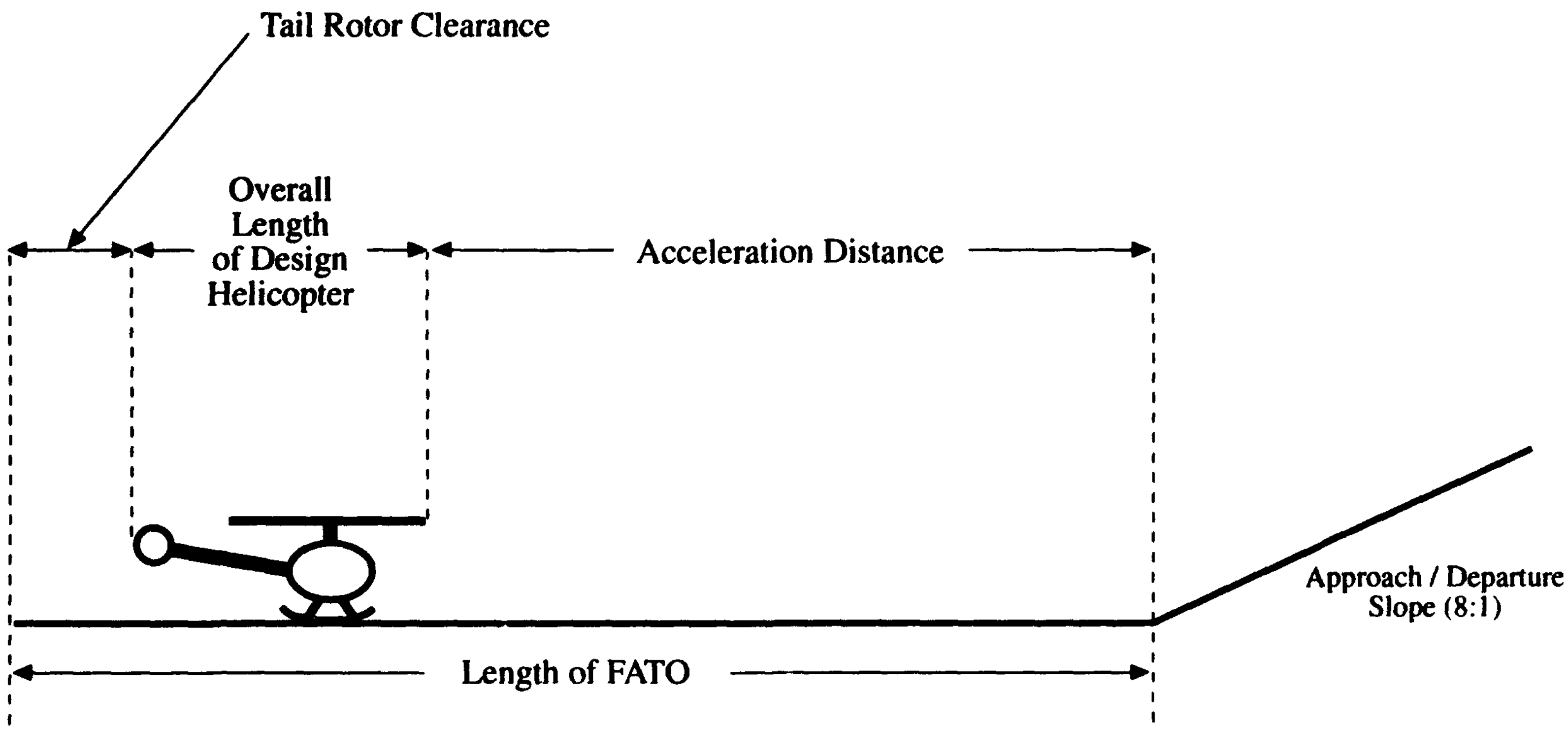


Figure 5. Relationship of the FATO
to the Acceleration Distance

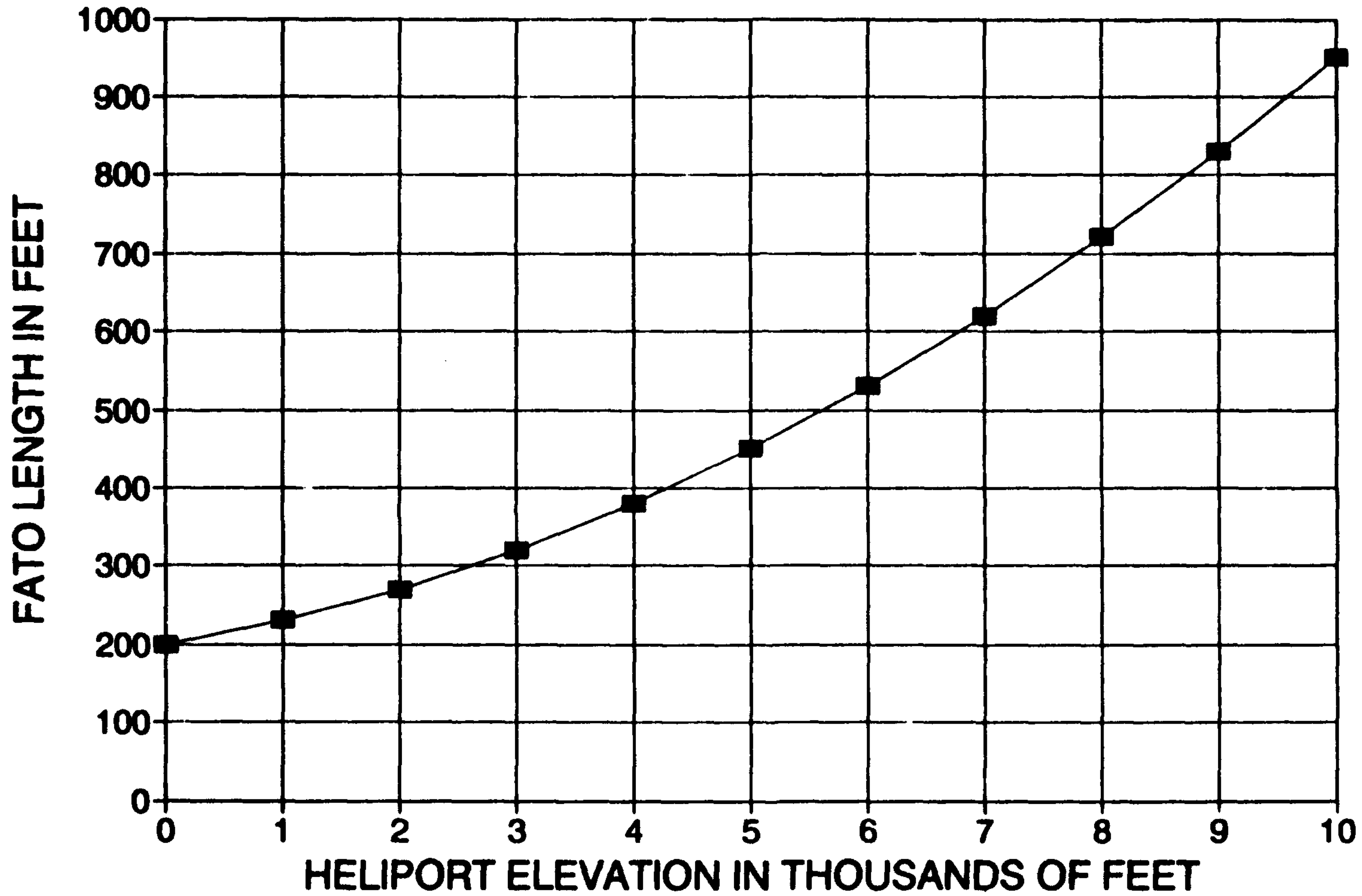


Figure 6. FATO Length Design Curve for Public Use Heliports

c. Flight Manuals - Confined Area Takeoff Procedures - Require helicopter manufacturers to include takeoff and landing procedures in the helicopter flight manuals for confined area heliport operations.

d. Provide and Publish Heliport Airspace Data - Develop procedures for measuring acceleration distances and climbout angles at heliports. Perform these measurements at public use facilities and publish the results in the airport facility directories containing this information. Encourage industry to provide similar information for private heliports. Include other useful operational data in the facility directory including heliport size, principal obstacles (azimuth, distance, and height above helipad), approach/departure paths, parking areas, services available, and operating policies.

e. Heliport VFR Imaginary Surface - Replace the single heliport imaginary surface with a surface or surfaces that give operational credit for helicopter performance. Require that the surface or surfaces provide adequate space for aircraft acceleration and provide a safety margin factor of 1.2 between allowable obstructions and aircraft climb capability. (Reference: Example presented in section 5 of report FAA/RD-90/4.) Revise Advisory Circular 150/5390-2 (Heliport Design) to incorporate design changes based on helicopter performance.

These long term changes should be viewed as a package. Any of the first four could and should be done independently. However, changes to the heliport VFR imaginary surfaces would require modification to the vertical flight infrastructure in order to maintain safety. Industry must decide whether the costs of these infrastructure changes are justified by the benefits that would result. The FAA does not plan to require these infrastructure changes unless the industry endorses them.

2.1.1.3 Operational Survey of Industry Helicopter Pilots. During the effort dealing with certification data (see section 2.1.1.2), FAA and industry personnel were briefed several times. During these briefings, both the FAA and industry recommended that an operational survey be conducted. The purpose of this survey was to compare actual operating procedures with the procedures assumed in FAA/RD-90/4. The results of this effort are documented in FAA/RD-90/5, Operational Survey - VFR Heliport Approaches and Departures. Among the more significant results of this effort are the following:

a. Ninety-eight percent of the surveyed pilots expressed concerns about the safety of vertical or steep approaches/departures, and about 50 percent indicated that the use of vertical or steep approaches/departures are only appropriate when required by the mission.

b. Pilots expressed a desire to avoid operating in the H-V curve. However, it is apparent that pilots often fly through portions of the height-velocity (H-V) curve that the FAA and the manufacturers recommend be avoided. Pilots typically had limited knowledge about the exact H-V curve for their aircraft and had to refer to their flight manuals for anything except broad approximations.

2.1.1.4 Helicopter Accident and Accident Rate Analyses. The acid test of how well the rotorcraft community is doing is in the day to day operations. What is the accident rate? Is this rate improving from year to year? How does it compare with the accident rates of other segments of the aviation industry? What kinds of accidents are occurring? Of those accidents that involve collisions with obstacles on approach or departure, were the obstacles inside or outside the minimum required VFR airspace? The FAA did such an analysis. This effort resulted in several reports:

FAA/RD-90/8, Analysis of Helicopter Mishaps At Heliports, Airports, and Unimproved Sites

FAA/RD-90/9, Analysis of Rotorcraft Accident Risk Exposure at Heliports and Airports

FAA/RD-91/1, Composite Profiles of Helicopter Mishaps at Heliports, Airports, and Unimproved Sites

The first of these reports (FAA/RD-90/8) contains an analysis of 117 helicopter mishaps. These were selected from approximately 4500 mishaps based on whether the mishap was likely to teach us something about heliport design requirements. Collisions with obstacles on approach or departure constitute a significant percentage of "heliport" accidents. Of the mishaps selected for detailed analysis, 19 percent took place during departures and 10 percent took place during approaches. Unfortunately, accident reports very seldom provide sufficient detail to determine if the obstacles were inside the minimum VFR heliport airspace. However, approach and departure accidents do indicate that collisions with obstacles are a significant problem (see section 2.4.2.1 for additional discussion on this issue).

The second document (FAA/RD-90/9) looks at overall helicopter accident rates and the risk associated with landing site design issues. Overall helicopter accident rates have dropped dramatically during the last several decades. Analysis shows that the accident rate for takeoff and landing accidents is also improving. While this is encouraging, approach and departure accidents constitute an area where continued improvement is needed. (More is said on this issue in section 6.0, Safety Perspective.) FAA/RD-90/9 documents the selection of a target level of safety (TLOS) that can be used to help continue the improvement in accident rates.

The third document (FAA/RD-91/1) contains examples of the types of accidents and incidents taking place at the various types of vertical flight landing sites. The FAA anticipates that airport/heliport/vertiport designers will take these three documents into consideration in the design process. In so doing, they can avoid by design potentially hazardous situations. This third document is intended primarily for use by landing site designers and by operators, primarily as a teaching document. However, pilots may also find it of interest as a way to become more aware of the types of accidents and incidents taking place at landing sites and how they can be avoided.

2.1.2 Curved VFR Approaches/Departures.

2.1.2.1 Flight Testing - Curved Approaches/Departures. Limited preliminary flight testing of VFR heliport curved approaches and departures was documented in report FAA/CT-TN87/40. Industry expressed great interest in the flexibility that curved approaches and departures can provide in heliport siting.

In collecting TERPS data on IFR operations, it has long been recognized that IFR operations on straight flight paths require less airspace (due to a smaller lateral dispersion) than what is required for IFR operations on curved flight paths. On this basis, it was reasonable to expect that curved approaches and departures at heliport will also consume more airspace than straight approaches and departures. The limited FAA/CT-TN87/40 data on heliport curved approaches and departures had tended to confirm this idea.

Additional flight testing of curved approaches has been completed. Results are documented in FAA/RD-TN92/46, VMC Left Turn Curved Approaches - Test Results. (Left turns, in comparison with right turns, are considered a worst case scenario. Testing of right turn approaches is documented in FAA/CT-TN93/24, Visual Meteorological Conditions (VMC) Right Turn Curved Approaches.) Approaches were flown with minimum straight segments of 800, 1200, and 1600 feet. Testing included procedures with intercept angles of 45, 90, and 180 degrees. (By intercept angle, we mean the angle between the initial approach azimuth and the azimuth of the extended centerline of the minimum straight segment prior to touchdown.)

Using a Sikorsky S-76, 19 subject pilots completed a total of 610 approaches. Using a Bell UH-1H, 16 subject pilots completed a total of 522 approaches. Subject pilots provided in-flight ratings of the various approaches. With regard to workload, safety, and controllability; the FAA requested pilot ratings within the following structure:

Group 1: acceptable procedure for routine operation
Group 2: acceptable only on occasion
Group 3: inadequate safety margin and major deficiencies

Of 3396 total ratings of left turn approaches, 3121 (91.9 percent) were in Group 1, 266 (7.8 percent) were in Group 2, and 9 (0.26 percent) were in Group 3. (Of the Group 3 ratings, 2 were from UH-1H pilots and 7 were from S-76 pilots. Of the Group 2 ratings, 70 were from UH-1H pilots and 196 were from S-76 pilots.) Of 973 total ratings of right turn approaches, 847 (87 percent) were in Group 1, 123 (12.7 percent) were in Group 2, and 2 (0.20 percent) were in Group 3.

Looking at the composite profiles of lateral dispersion, it is clear that the lateral dispersion during the curve is broader than the lateral dispersion at the same distance from the helipad for a straight approach. This is even true at both end of the final straight segment of the approach.

While curved approaches and departures require more airspace, they do offer greater flexibility in siting heliports. Thus, it would be appropriate to quantify these airspace requirements in order to allow industry to take advantage of this flexibility. Federal Aviation Regulations (FAR) Part 77 should be modified to address the larger airspace required for VFR heliport curved approaches and departures. Changes are also appropriate in the Heliport Design advisory circular.

2.1.2.2 Operational Survey of Industry Helicopter Pilots. The subject of shallow 10 degree turns was addressed subjectively in report FAA/RD-90/5, Operational Survey - VFR Heliport Approaches and Departures. For an intercept angle as small as 10 degrees, the lateral dispersion of the approach and departure airspace should not need to be increased over what is required for straight approaches/departures.

2.1.2.3 Minimum Straight Segment on Curved Approaches. Some in industry have expressed concern about the 1200 foot straight segment used in the curved approach/departure flights documented in FAA/CT-TN87/40. They have argued for a minimum straight segment as short as zero feet in length. With a zero foot straight segment, a pilot would be required to make a curved approach where the higher workload associated with the curve would continue until touchdown.

Additional flight testing of curved approaches has been completed, as discussed in section 2.1.2.1, and results are published in FAA/CT-TN92/46 (and soon to be published in FAA/CT-TN93/24). Approaches were flown with minimum straight segments of 800, 1200, and 1600 feet. Testing included procedures with intercept angles of 45, 90, and 180 degrees. (By intercept angle, we mean the angle between the initial approach azimuth and the azimuth of the minimum straight segment prior to touchdown.) Results indicate that a significant number of pilots are uncomfortable with a straight segment that is less than 1200 feet in length. Some of the subject pilots expressed concern about the higher workload and smaller safety margin associated with a

straight segment shorter than 1200 feet. Passenger comfort is also an important issue.

2.1.3 Heliport Rejected Takeoff Airspace. Analysis of this issue is documented in FAA/RD-90/7, Helicopter Rejected Takeoff Airspace Requirements. This report contains an analysis of performance data for helicopters that are certified for Category A operations. It relates rejected takeoff and one engine inoperative (OEI) performance capability to airspace requirements for heliports intended to support Category A operations.

Currently, the airspace defined in the 1994 Heliport Design advisory circular does not take into account emergency situations involving engine failures during takeoff and landing operations. More specifically, the air and ground space defined in AC 150-5390-2A and in FAR Part 77 are inadequate to cover the range of helicopters and conditions that are encountered during rejected takeoff or climbout with one engine inoperative.

The climbout angle requirements in the current AC 150-5390-2A are too steep for many of the OEI climbout conditions that are typically encountered. The climbout angles identified in this study ranged from a high of 20 degrees to a low of 1 degree for helicopters operating with Category A OEI restrictions. The standard 8:1 slope (7.125 degrees) is too steep for most OEI climbout cases observed in this study.

This report focused on the airspace required for rejected takeoffs by helicopters operating to Category A requirements. This document did not address the issue of when Category A operations should be required.

2.1.4 Summary - Minimum Heliport VFR Airspace. The FAA has studied this issue in a multi-faceted R&D program involving flight testing, analysis of certification data, operational survey of industry helicopter pilots, and helicopter accident analysis. To varying degrees, each facet of this effort indicates a need for an increase in the minimum recommended VFR heliport airspace.

Results indicate that three principal changes are required. First, the lateral dimension of the outer edge of the VFR approach/ departure airspace needs to be increased from 500 feet to 1040 feet. Second, obstructions in the vicinity of a heliport and its approach/departure paths need to be marked and lighted (see figure 4). Third, an acceleration area needs to be added prior to the start of the approach/departure surface. The distance required is a function of altitude as follows:

$$\text{acceleration distance} = 140 + 25(x) + 5(x)^2 \text{ feet}$$

where x is the site elevation in thousands of feet.

With this acceleration distance, the current 8:1 slope of the approach/departure surface could be retained for heliports at an elevation of 3000 feet or less. For heliports above 3000 feet, the approach/departure surface slope should not be steeper than 9:1 even with the acceleration distance given above.

It should be recognized that the length of the FATO must be longer than the desired acceleration distance. As shown in figure 5, the length of the FATO includes the acceleration distance, the length of the helicopter, and the tip clearance required for the tail rotor. Taking all this into account, the minimum FATO recommended for public use heliports is shown in figure 6.

The Heliport Design AC should be modified to include this acceleration distance. With regard to the airspace and obstruction marking changes, such changes should first be made in FAR 77, Objects Affecting Navigable Airspace. Then, appropriate changes would be made in the Heliport Design AC and the Vertiport Design AC.

In the longer term, greater flexibility is possible in developing VFR heliports with a steeper than 8:1 primary surface. However, there are changes that would have to be made in the infrastructure to support safe operations under this scenario (see document FAA/RD-90/4).

2.1.5 Future Work - Minimum Heliport VFR Airspace. Attention on the VFR airspace issue has largely focused on scenarios with a limited number of obstacles. Some in the rotorcraft community have questioned how pilots would respond to a facility in an "obstacle-rich" environment. They are envisioning a facility with a "picket fence" of skyscrapers on each side of the approach and a large number of objects just under the 8:1 surface of this path. Consider a scenario where none of these individual objects is technically an obstacle (as defined by FAR 77). In concert together, however, the psychological effect they produce might be overwhelming. Pilots might consider such a facility unsafe even though it met all the current public heliport requirements. Operators might decline to operate there with single engine helicopters in order to avoid the negative public relations effects involved in an accident.

In the November 1990 Rotorcraft Master Plan, the FAA published the following strategy:

I-7) Promote construction of at least

- a total of 100 public use heliports and vertiports by the year 2000,
- a total of 250 public use heliports and vertiports by the year 2005,

- a total of 500 public use heliports and vertiports by the year 2010,

ensuring that 40 percent of the above public use heliports and vertiports are fully IFR capable by 2010.

In recent years, the public heliports funded by the FAA have been downtown heliports. When acquisition of property has been required, these have been expensive facilities, often in excess of $5 million. Considering the size of the investment, these facilities need to be built to a standard that will ensure that both the pilots and the public will consider them safe. With this in mind, the FAA has started to develop plans for simulation testing of VFR operations at a heliport located in an "obstacle-rich" environment (see section 4.0).

In addition to all of the work that has been done with helicopters, similar testing would be required for various powered-lift aircraft such as the tiltrotor.

2.2 <u>Parking and Maneuvering Areas</u>. Minimum dimensions required of heliport parking areas have been a topic of discussion for several decades. In recent years, the FAA has published several documents on this issue.

2.2.1 Initial Survey of Industry Helicopter Pilots. During the summer of 1987, the FAA interviewed 28 helicopter pilots at the Indianapolis Downtown Heliport and 22 helicopter pilots at the Downtown Manhattan Heliport (Wall Street). These pilots were asked for their opinions concerning safe maneuvering clearances between their rotor tips and other objects. The range of the answers varied tremendously from 4 to 150 feet. Although they were almost all high-time pilots (86% had in excess of 3000 flight hours), only one third of these pilots were comfortable with the helicopter/object and helicopter/helicopter separations recommended in the 1988 Heliport Design AC (one third rotor diameter but not less than 10 feet). Results are documented in FAA/CT-TN87/54, Analysis of Helicopter Environmental Data: Indianapolis Downtown Heliport, Wall Street Heliport, Volume I Summary.

2.2.2 Additional Survey of Industry Helicopter Pilots. Industry pilots in the NY/NJ area, Louisiana, and Texas responded to questions concerning rotor tip clearances. (The questionnaire was similar to the one used in the effort discussed in section 2.2.1. but it addressed wind conditions as a variable. There was no duplication in the pilots involved in these two surveys.) In their responses, these 203 pilots were considerably more conservative than the 13 subject pilots (see section 2.2.3). Depending on wind conditions and on whether or not the object was an aircraft, only 19 to 41 percent of these pilots said that they were comfortable with rotor tip clearances of one third rotor diameter. Between 19 and 43 percent said that they were

uncomfortable with less than one half rotor diameter tip clearances. Between 5 to 17 percent said that they were uncomfortable with less than a full rotor diameter tip clearance. Results are documented in FAA/CT-TN88/30, Heliport Surface Maneuvering Test Results.

Initially, the results of the industry pilot questionnaires appeared to support minimum parking area dimensions that provide a minimum tip clearance of one full rotor diameter for air taxi maneuvers. Upon closer examination (and additional testing), however, the FAA has reached different conclusions (See section 2.2.4 and Appendix B).

2.2.3 Initial Ground Maneuvering Flight Testing - UH-1H. Following up on the initial pilot survey, the FAA conducted flight testing on this issue. Results are documented in FAA/CT-TN88/30, Heliport Surface Maneuvering Test Results. This report documents daylight flight tests of 13 pilots in a UH-1 helicopter (rotor diameter: 48 feet). At the time the flight testing was done, the UH-1 was a DOD aircraft. Consequently, the FAA was contractually limited to the use of subject pilots who were qualified and current in the UH-1 under the military's rules. The 13 subject pilots were either National Guard pilots, FAA test pilots, or both. When interviewed after their flight testing, the majority of these pilots stated that they were comfortable with rotor tip clearances of one third the rotor diameter or less (page 12, table 6). During actual parking maneuvers, however, the pilots' actual rotor tip clearances averaged between 1.1 and 1.6 times their stated preference. (During actual flight testing, they were more conservative than their verbal statements.) Taken at face value, the results of the flight testing would support minimum parking area dimensions that provide a tip clearance between one third and one half of the rotor diameter.

2.2.4 Comparison - Flight Testing and Pilot Surveys. Initially, it appeared that the results of the flight testing (section 2.2.3) and the results of the subjective industry pilots survey (sections 2.2.1 and 2.2.2) were seriously in conflict. This led the FAA to reexamine the survey data and this has resulted in an interesting discovery (See Appendix B for this analysis.).

It has long been assumed that tip clearances required for safe ground operations are **directly** proportional to the size of the rotor diameter. However, subsequent analysis of the survey data initially indicated that the relationship might be **indirectly** proportional within certain limits. As the rotors get smaller, industry pilots expressed a need for a larger tip clearance. Several reasons were postulated for this unexpected result:

- Helicopters with rotor diameters of less than 30 feet are light in weight. Small helicopters are more likely to be

blown around by the wind than larger helicopters. This is particularly the case when the larger helicopters have wheeled landing gear.

o Helicopters with rotor diameters of less than 30 feet are skid equipped. They hover taxi rather than ground taxi.

o Helicopters with larger rotor diameters also tend to taller. When the pilot's seat is higher, it provides a better perspective during ground maneuvering. This viewing angle may be helpful in terms of judging distances.

o Low time pilots are far more likely to be flying a small helicopter.

Any or all of these reasons could explain why pilots of smaller helicopters have expressed a desire for a larger tip clearance.

The flight testing discussed in section 2.2.3 was done in a helicopter with a rotor diameter of 48 feet. The subject pilots were content with a tip clearance of 16 feet whereas the median (50 percentile) surveyed pilot wanted 20 feet and the 90 percentile pilot wanted 30 feet. With the Appendix B reexamination of the data, there was less divergence between the results of the flight testing (section 2.2.3) and the results of the subjective industry pilots survey (sections 2.2.1 and 2.2.2). At the same time, however, this analysis showed that, for pilots of helicopters with a 25 foot rotor diameter, the 50 percentile pilot wants 40 feet of tip clearance (see Appendix B and section 2.2.6).

2.2.5 Ground Maneuvering Testing at Night. In low level lighting, visual cues deteriorate along with pilot depth perception. Testing was therefore conducted to determine whether larger maneuvering areas are needed at night for operation under low ambient light conditions. Results are documented in FAA/CT-TN92/1, Helicopter Nighttime Parking Test Results - UH-1. Among the conclusions of this report are the following:

1. During the first portion of the testing, each pilot was asked to state the rotor tip clearance with which he/she would be comfortable. The pilot was then instructed to park parallel to the obstacle with this stated clearance. During this portion of the testing, there were FIVE occasions when the main rotor blades overlapped the test obstacle. (Three of these overlaps occurred when the obstacle was lit. Two overlaps occurred when the obstacle was unlit.)

2. For safety's sake, the height of the obstacle was a few feet shorter than the main rotor height in a rotor-level configuration. Had the obstacle been a few feet higher during any of the FIVE overlaps experienced during the testing, a serious accident could have resulted.

The five overlaps represent four percent of the total number of operations in the testing. This demonstrates that the current one third rotor diameter tip clearance is inadequate even with high time helicopter pilots.

The nighttime ground maneuvering testing was very similar to the earlier daytime testing documented in FAA/CT-TN88/30, Heliport Surface Maneuvering Test Results. Nighttime operations require about 25 percent additional tip clearances to compensate for the deterioration of visual cues in low ambient lighting.

2.2.6 Ground Maneuvering Testing - R-22. The FAA tested 40 subject pilots in a Robinson R-22 helicopter (rotor diameter: 25.2 feet) using procedures similar to the testing documented in FAA/CT-TN88/30. Results of this effort are documented in FAA/CT-TN93/6, Combined 1991 and 1992 Robinson - 22B (R-22) Parking Test Results. When the subject pilots were asked to park with an unspecified "safe" rotor tip clearance from another aircraft or from a ground marking, actual tip clearances varied from 1.51 to 23.64 feet with an average of 11.0 feet. When the subject pilots were asked to park with a rotor tip clearance of 10 feet, actual tip clearances varied from 2.88 to 25.94 feet with an average of 14.5 feet. During the various tests, pilot perception errors (actual tip clearance minus the pilot's estimate of the tip clearance) were as large as 17 feet.

One should realise that these subject pilots were aware of the analysis of Appendix B (Specifically that the 50 percentile pilot wanted 40 feet of tip clearance when flying an R-22.). Discussion has raised a concern that a number of the subject pilots may have been motivated to perform in a way that support the tip clearance requirements of the 1988 Heliport Design AC (10 feet tip clearance for an R-22), thereby disproving the need for a 40 foot tip clearance when hovering an R-22.

The results of FAA/CT-TN93/6 do lead one to conclude that a 40 foot tip clearance would be more than the minimum requirement. However, FAA/CT-TN93/6 also shows conclusively that a 10 foot tip clearance requirement is inadequate for an R-22. Rather, the results point to a minimum requirement of about 20 - 25 feet. This is just slightly larger than the 20 feet tip clearance desired by the 50 percentile pilot in rotorcraft with rotor diameters of 30 feet or larger (see Appendix B, figure 4). However, it is considerably smaller than the 40 feet tip clearance desired by the 50 percentile pilot in rotorcraft with rotor diameters of 25 feet.

2.2.7 Accident Analysis - Parking and Maneuvering Areas. The acid test of how well the rotorcraft community is doing is in the day to day operations. What is the accident rate for collisions with obstacles during ground maneuvers? Is this rate improving from year to year? How does it compare with helicopter accident rates in other phases of operation? The FAA studied helicopter

accidents and incidents with these questions in mind. This effort resulted in several reports:

FAA/RD-90/8, Analysis of Helicopter Mishaps At Heliports, Airports, and Unimproved Sites

FAA/RD-90/9, Analysis of Rotorcraft Accident Risk Exposure at Heliports and Airports

FAA/RD-91/1, Composite Profiles of Helicopter Mishaps at Heliports, Airports, and Unimproved Sites

The first of these reports (FAA/RD-90/8) contains an analysis of 117 helicopter mishaps. These were selected from approximately 4500 mishaps based on whether the mishap was likely to teach us something about heliport design requirements. Of the mishaps selected for detailed analysis, 36 percent of those that took place on heliports and 59 percent of those that took place at airports involved obstruction strikes during operations on the ground. Obviously, obstruction strikes are a significant issue that needs to be addressed.

The second document (FAA/RD-90/9) looks at overall helicopter accident rates and the risk associated with landing site design issues. Overall helicopter accident rates have dropped dramatically during the last several decades. Analysis shows, however, that during the 1970's and the 1980's, the accident rate for ground maneuvering accidents has not been improving. If the overall helicopter accident rate improvement is to continue, improvements are necessary in virtually all categories of accidents.

The third document (FAA/RD-91/1) contains examples of the types of accidents and incidents taking place at the various types of vertical flight landing sites. The FAA anticipates that airport/heliport/vertiport designers will take these three documents into consideration in the design process. In so doing, they can avoid by design potentially hazardous situations. This third document is intended primarily for use by landing site designers and by operators, primarily as a teaching document. However, pilots may also find it of interest as a way to become more aware of the types of accidents and incidents taking place at landing sites and how they can be avoided.

2.2.8 Parking Area Markings - Maximum Rotor Diameter. During the 1984-88 revision of the 1977 Heliport Design AC, the FAA/Industry Working Group discussed the possibility of marking each parking spot with the maximum rotor diameter that the parking spot can accommodate safely. This recommendation was not included in the published 1988 Heliport Design AC. However, subsequent accident analysis indicates that collisions with obstacles during ground maneuvering and parking is a problem area. A significant percentage of helicopter accidents on the

ground involve collisions with obstacles. In addition, the NTSB, in response to an accident at the Wall Street Heliport, has recommended the adoption of a requirement to mark each parking spot with the maximum rotor diameter that the parking spot can accommodate safely. This could be a valuable safety improvement. At the same time, however, the conventional design wisdom needs to be fundamentally reexamined (see Appendix B).

2.2.9 Summary - Parking and Maneuvering Areas. Based largely on the testing documented in FAA/CT-TN88/30, the FAA adopted a tip clearance of one half the rotor span of a tiltrotor aircraft in the Vertiport Design Advisory Circular AC150/5390-3. As the FAA/industry group revised the 1988 Heliport Design AC, one of the issues to be addressed was whether one half rotor diameter would provide an appropriate safety margin for heliport design. Closer examination of the data in FAA/CT-TN88/30 and FAA/CT-TN93/6 provides some interesting insights on this question. (This topic is discussed in detail in Appendix B.)

In summary, flight testing, subjective pilot surveys, and accident analysis all support the requirement for additional parking and maneuvering space. The political issue is, "How much should they be increased?" The issue of cost can not be ignored.

(As it gains maturity, the work on rotorwash discussed in section 2.3 will also have an impact on the issue of parking areas.)

2.2.10 Future Work - Parking and Maneuvering Areas. In addition to the work on helicopters, similar testing is required for various powered-lift aircraft such as the tiltrotor.

2.3 Rotorwash. The majority of civil helicopters are light in weight and it is rare for them to cause a rotorwash-related mishap. As rotorcraft increase in weight, they are capable of generating greater rotorwash. Thus, with heavy rotorcraft, rotorwash-related mishaps are more of a concern. The Heliport Design Advisory Circular addresses this issue indirectly and to a limited degree. By and large, however, the assurance of safety is the responsibility of the pilot. When this fails, the operator is responsible for damages and presumably takes appropriate action to preclude future mishaps.

Anticipating the introduction of large helicopters (and the tiltrotor) at public facilities, it is appropriate to consider whether protection against rotorwash mishaps should continue to depend so heavily on pilot judgment. Would it not be better to provide a larger safety margin by addressing this issue via facility design and operational procedures guidelines? This is the avenue that the FAA has been pursuing.

The FAA approach to this task has been four-fold:

a. measure rotorwash of existing helicopter and vertical flight aircraft such as the tiltrotor. Make use of data collected by other government agencies.

b. develop and validate a rotorwash computer model based on the available rotorwash data.

c. analyze rotorwash induced mishaps and determine the threshold(s) at which rotorwash becomes a potential hazard.

d. apply the model to an analysis of a variety of operational scenarios using this threshold(s) and determine how to alleviate this type of mishap by avoiding these potential hazards.

Each of these facets is discussed in the following paragraphs.

2.3.1 Rotorwash Measurement. The FAA has collected rotorwash data in an effort to better understand the rotorwash phenomenon and the operational environment at vertical flight landing sites. Results are published in the following reports:

FAA/CT-TN87/54, Analysis of Heliport Environmental Data: Indianapolis Heliport, Wall Street Heliport

Vol. 1, Summary
Vol. 2, Wall Street Heliport Data Plots
Vol. 3, Indianapolis Downtown Heliport Data Plots

FAA/CT-TN89/43 Analysis of Heliport Environmental Data: Intracoastal City, LA.

The measured data in these documents describe the magnitude of the rotorwash generated by different types of helicopters in actual operations at various locations. The data collected at Intracoastal City involved a large number of helicopters, many of which were larger than those seen at the other locations.

These data were collected using a electro-mechanical sensor, specifically, a Belford Instrument Company S-122 HD Wind Vector Transmitter. These transmitters consist of two major elements: an upper section containing a wind speed generator attached to an airplane rudder shaped vane, and a fixed, vertical support and connector housing. The wind speed generator is driven by a six-blade propeller. Due to the inertia characteristics of this device, questions were raised as to whether this type of electro-mechanical sensor under-reports the peak pulses of the rotorwash.

In the late 1980's, in anticipation of additional rotorwash testing, the FAA Technical Center replaced their Belford wind sensors with Qualimetrics Model 2132 wind speed and direction sensors. (The Belford wind sensors were sold as surplus government equipment.) Although the original wind sensors were

no longer available for testing, the FAA still wanted to gain a better understanding of the characteristics and limitations of electro-mechanical sensors.

Rotorwash data have also been collected by the Navy's Systems Engineering Test Directorate at the Patuxent River Naval Air Station using a two axis ion beam deflection anemometer. This device is considered to be perhaps the best available instrument for measuring rotorwash velocity. The FAA funded a comparison of the two types of wind sensors. Report FAA/RD-93/10, Rotorwash Wind Sensor Evaluation, documents the results. Test conditions included both wind tunnel testing and side-by-side testing in close proximity to a hovering helicopter.

Test results show that the Qualimetrics Model 2132 Wind Sensor does not accurately measure a rotorwash flow field in terms of frequency amplitude, frequency content and velocity magnitude. Thus, it is not recommended for helicopter rotorwash velocity data collection. Although the Belford Instrument Company S-122 HD Wind Vector Transmitter was not specifically tested, as a electro-mechanical sensor, it is reasonable to expect that it has the same physical limitations as the Qualimetrics sensor.

What are the implications of this wind sensor comparison with regard to the data contained in reports FAA/CT-TN87/54 and FAA/CT-TN89/43?

- The rotorwash data in these documents allow a reasonable comparison between the relative magnitude of the rotorwash characteristics of different helicopters.

- However, the data in these documents significantly underestimate the severity of the rotorwash phenomenon. With the peak wind velocity, for instance, a limited sample shows that the Qualimetrics Model 2132 sensor under-reported the peak velocity by as much as 19 knots in comparison with an ion beam deflection wind sensor.

Extensive rotorwash data have also been collected by other federal agencies on a number of vehicles. The FAA has taken advantage of these data in this effort.

2.3.2 Rotorwash Computer Model. Using the available rotorwash data, the FAA has developed a rotorwash computer model. (In addition to the data collected by the FAA, we have made use of rotorwash data collected by the military on helicopters, the XV-15 tiltrotor, and preliminary measurements of the V-22 Osprey.) A user's guide for this program is contained in FAA/RD-90/25, Rotorwash Computer Model - User's Guide. (An updated version of this document is in process and will be published shortly (FAA/RD-93/31, Rotorwash Analysis Handbook).)

Using this computer program, the FAA has modelled the rotorwash expected from a variety of tiltrotor and tiltwing aircraft. Results are documented in FAA/RD-90/16, Evaluation of Rotorwash Characteristics for Tiltrotor and Tiltwing Aircraft in Hovering Flight.

Among the more significant conclusions of this evaluation are the following:

a. Depending on the various factors involved, ALL evaluated configurations do have the potential to create rotorwash related hazards. These hazards will have to be addressed through vertiport design and vertiport operating procedures.

b. The small tiltrotor configurations (XV-15, Magnum Tiltrotor, CTR-800, and CTR-1900) should not create significant rotorwash related problems when operated at most planned vertiports.

c. Operation of the small tiltwing configurations (CL-84 and TW-68) should not create significant rotorwash related problems when operated at most planned vertiports. However, both of these tiltwing aircraft do generate levels of rotorwash in close proximity to the aircraft that may result in significant amounts of entrained particles being ejected out all azimuths for some types of landing surfaces.

d. Additional research and development is required. (This topic is discussed in section 2.3.6.)

2.3.3 Analysis of Rotorwash Mishaps. The FAA has analyzed a number of accidents and incidents that were caused by rotorwash. Using the model described in FAA/RD-90/25, the intent was to identify threshold levels where rotorwash becomes potentially hazardous. This effort is documented in report FAA/RD-90/17, Analysis of Rotorwash Mishaps. For purposes of discussion, let us define two points D and S shown below.

..........D.......................S...................

Consider the continuum of operations that might take place at a heliport and consider the rotorwash resulting from these operations. Analysis can show that everything to the left of D is dangerous and that everything to the right of S is safe. The definitely dangerous situations can be avoided through heliport design. The definitely safe situations present no problems. Due to the complexity of the rotorwash issue, however, there is a lot of ground between points D and S where the situation is gray rather than black or white.

Economically, it is not practical to preclude (via heliport design or operational restrictions) all heliport operations that

fall between points D and S. It is the pilot's responsibility to avoid situations that are dangerous.

Anticipating the introduction of larger rotorcraft at public heliports/vertiports, the FAA is trying to gain a better understanding of the rotorwash phenomenon. By analyzing accidents/mishaps involving rotorwash, the FAA intent is to determine the thresholds at which rotorwash creates a potential hazard in a variety of scenarios. In so doing, it should be possible to reduce the distance between points D and S.

Due to the lack of detailed mishap data, critical threshold values of rotorwash velocity could not be conclusively identified. However, critical ranges of combined rotorwash and ambient velocity were identified for several types of mishaps investigated. These ranges of peak velocity occur between approximately 30 and 40 knots. Additional research and development is recommended (see section 2.3.6).

2.3.4 Analysis of Operational Scenarios. This facet of the rotorwash effort has not yet been initiated. However, industry feedback on the results of the efforts described in sections 2.3.2 and 2.3.3 indicate that it is appropriate to undertake this analysis.

2.3.5 Summary - Rotorwash. With the introduction of larger helicopters (and tiltrotor) at public facilities, the risk of rotorwash-induced accidents would increase. It would be safer not to depend too heavily on pilot judgment to avoid all potential hazardous situations involving rotorwash. It appears that some potential hazards can best be avoided by implementing operational constraints. Others will be best addressed by precluding the hazard via facility design. However, rotorwash is an extremely complex phenomenon. On some rotorwash issues, additional work is required before informed choices can be made as to how these specific rotorwash hazards can best be addressed. At this point, it is premature to speculate on how the details of all aspects of the rotorwash issue will be resolved.

2.3.6 Future Work - Rotorwash. As discussed in section 2.3.2, one primary conclusion of the work to date has been the need for additional R&D. The following specific actions need to be taken:

a. Develop a method for determining the maximum size of the tiltrotor and tiltwing configurations that can be operated safely within a given distance of parked aircraft, ramp equipment/crews, and/or ground crew/passengers in the open (operating procedures should be factored into this process).

b. Correlate additional V-22 Osprey rotorwash flight test data with the rotorwash computer program documented in report FAA/RD-93/31.

c. Acquire rotorwash flight data documenting the effect of both wind and maneuvering near hover. (Without these data, questions will continue to exist with respect to the definition of the worst case scenarios in all safety analyses.) A test plan (RD-92-1-LR) has been developed for this purpose.

d. Determine if a serious hazard potential exists for the entrainment in the outwash flow field of small particles from the landing surface (i.e., gravel).

e. Conduct flight tests to define acceptable limits of overturning force and moment values for civilian ramp personnel and passengers. (These data will allow industry to choose among several alternatives in vertiport design: large gate separations allowing independent operations at adjacent gates, smaller gate separations requiring restrictions on passenger loading/unloading at gate A while an aircraft is taxiing to or from the adjacent gate B, or the use of enclosed walkways/jetways for passenger loading/unloading.) A test plan (RD-92-2-LR) has been developed for this purpose.

f. Analyze a variety of operational scenarios using rotorwash safety thresholds and determining how to prevent rotorwash accidents and incidents.

2.4 Helicopter Accident/Incident Analysis. The acid test of whether we, the rotorcraft community, are doing things correctly is in the daily operations and the associated accident/incidents. The accident/incident records can tell us when we have failed this test and where we need to improve. In recent years, the FAA has conducted several analyses of accidents and incidents. These analyses are discussed below.

2.4.1 General Helicopter Accident Analysis. The first of these efforts is documented in FAA/PM-86/28, Investigation of Hazards of Helicopter Operations and Root Causes of Helicopter Accidents. This first report documents a broad investigation of helicopter accidents. Based in part on the results of this effort, the FAA has conducted several other rotorcraft accident analyses. Each analysis focused on a specific subset of accidents.

2.4.2 Helicopter Landing Site Accident/Incident Analysis. This analysis looked specifically at accidents and incidents that took place at or near heliports, airports, and unimproved sites. Safety is sometimes a highly emotional issue when a heliport is proposed near a residential neighborhood. Prior to this effort, no one had ever done a detailed analysis to quantify this subset of the overall rotorcraft accident history. In the role of an "honest broker," the FAA has conducted a detailed analysis of helicopter accidents at different types of landing sites. FAA expectations are that these reports, particularly the first two

of the three reports, can be used by both heliport proponents and opponents as an objective statement on the safety of helicopter landing sites. Results both positive and negative are documented in the following reports:

FAA/RD-90/8, Analysis of Helicopter Mishaps At Heliports, Airports, and Unimproved Sites.

FAA/RD-90/9, Analysis of Rotorcraft Accident Risk Exposure at Heliports and Airports

FAA/RD-91/1, Composite Profiles of Helicopter Mishaps at Heliports, Airports, and Unimproved Sites

These documents are discussed below in sections 2.4.2.1 through 2.4.2.3.

2.4.2.1 Landing Site Accident/Incident Analysis. In the first document (FAA/RD-90/8), the analysis looked at helicopter accidents/incidents at or near 3 types of landing sites: heliports, airports, and undesignated/unimproved/remote heliports. The intent of this analysis was threefold:

- To gain a better understanding of the types of accidents that occur on and near helicopter landing sites (airports, heliports, and unimproved sites),

- To determine if the 1988 Heliport Design AC recommendations are adequate, and

- To make recommendations concerning any areas in the 1988 Heliport Design AC that may need to be revised, expanded, or emphasized.

This report provides histograms of the types of helicopter mishaps occurring airports, heliports, and unimproved sites. Landing site designers would do well to consider how such accidents can be avoided by facility design. At all 3 types of landing sites, a significant percentage of the accidents involved collisions with obstructions. These involved obstruction strikes while ground maneuvering and during approach and departure. At airports, the percentage of rotorcraft accidents involving obstruction strikes while ground maneuvering is particularly high. Among the conclusions of this effort are the following:

a. Overall, the 1988 FAA Heliport Design AC provided good guidance.

b. Many of the accidents analyzed might not have occurred if the 1988 Heliport Design AC recommendations had been satisfied at the operating location.

c. Certain areas need to be addressed, expanded, or emphasized in future revisions of this AC.

Based on this analysis, a number of changes were needed in the 1988 Heliport Design AC. Some of the more significant recommendations are listed below. (In the 1994 Heliport Design AC, some but not all of these recommendations have been adopted.)

d. Expand Chapter 4 of the 1988 Heliport Design AC substantially to mitigate the high percentage of rotorcraft accidents involving obstruction strikes while ground maneuvering on airports. (Obstruction strikes are the leading cause of helicopter mishaps at airports. The percentage of accidents involving obstruction strikes was nearly five times the percentage of the next largest cause factor.)

e. Add a requirement for marking obstructions, particularly wires, in the vicinity of the helipad and approach/departure paths. This is needed in order to mitigate accidents involving collisions with obstructions.

f. Increase the requirements for cleared area/airspace for departure paths.

g. Add a requirement for more than one wind sock at a facility under certain circumstances. (While landing site accidents indicate that one sock is required at some facilities, these accidents also highlight the need for a wind sock at all landing sites (except rarely used temporary sites). A wind sock provides much better information than a "wind indicator", such as a flag on a pole, at roughly the same cost.)

h. Place additional emphasis on heliport surface composition and maintenance.

2.4.2.2 Risk Analysis. The second document (FAA/RD-90/9) looks at overall helicopter accident rates and the risk associated with landing site design issues. As shown in figure 7, helicopter accident rates have decreased significantly over the years. In 1966, the helicopter accident rate was greater than 60 accident per 100,000 flight hours. By comparison, in 1989, the helicopter accident rate was less than 7 accident per 100,000 flight hours. When a heliport is proposed, community objections often focus on the issue of safety and the concern that there is a risk associated with having a heliport as a neighbor. Analysis of accident data shows emphatically that heliports are safe neighbors. While people often voice concerns about the possibility of a helicopter accident causing them personal injury or property damage, this document shows that such an event is extremely rare. Heliport proponents may find this document

useful as an authoritative reference in responding to community concerns.

Figure 8 is an excerpt from report FAA/RD-90/9 showing the neighborhood risk exposure as a function of the annual number of missions. The accidents of interest in this figure are rotorcraft accidents that cause either personal injury or property damage. At a heliport with 400 operations per year, the average likelihood of such an event within one mile of the heliport is one accident in 495 years.

At the same time, however, this analysis shows that, during the 1977 - 1986 time period, 34-39 percent of all helicopter accidents occurred at or within one mile of landing sites. (The majority of these accidents occur at the landing site itself but some occurred on approach or departure.) Approximately 13-18 percent of these helicopter accidents occurred at or near airports. Approximately 9-18 percent of these helicopter accidents occurred at or near unimproved landing sites. Approximately 3-5 percent of these helicopter accidents occurred at or near heliports. With approximately 3-8 percent of all helicopter accidents, National Transportation Safety Board records do not specify the nature of the landing site.

In all facets of aviation, accident analysis shows that takeoffs and landings pose a higher risk than en route flight. Analysis shows that this is also true for rotorcraft operations. Clearly, if the rotorcraft community is to continue to reduce its accident rates, reductions must be achieved in the number of accidents taking place at or near landing sites. Such reductions can be achieved through a combination of actions including training, design, operational procedures, etc. Reports FAA/RD-90/8, FAA/RD-90/9, and FAA/RD-91/1 all focus heavily on what should be done via changes in landing site design, design standards, and design guidelines.

Overall helicopter accident rates have dropped dramatically during the last several decades. Analysis shows that the accident rate for takeoff and landing accidents is also improving. While this is encouraging, approach and departure accidents constitute an area where continued improvement is needed. Analysis shows, however, that the accident rate for ground maneuvering accidents is not improving. If the overall helicopter accident rate improvement is to continue, improvements are necessary in virtually all categories of accidents. The ground maneuvering accident rate did not improved over a period of a decade. This lack of improvement indicates a need for design improvements via larger parking/maneuvering areas and for better/more consistent marking of parking areas.

Safety is a relative concept. What is safe in the eyes of one party may be unsafe in the eyes of another. When discussions of safety are based only on operational experience and subjective

opinions, these discussions tend not to be constructive. Objective test data can help focus discussions in ways that are constructive but this alone is not necessarily sufficient to reach consensus. Some method or standard is needed if the rotorcraft community is to draw a line between what is "safe" and acceptable and what is unacceptable.

One way to accomplish this is by developing a "target level of safety." The use of a target level of safety and the various methods for choosing it were discussed in FAA/DS-88/12. In FAA/RD-90/9, several specific targets are proposed based on rotorcraft accident analysis. These include target levels of safety for approach and departure operations and for ground maneuvering operations. These targets can help the rotorcraft community work together to reduce these types of accidents. Coupled with other objective test data, they also provide a means of defining the minimum requirements for heliport parking areas, taxiways, and VFR approach and departure airspace.

2.4.2.3 Composite Landing Site Accidents/Incidents. The third document (FAA/RD-91/1) is a continuation of the effort that produced FAA/RD-90/8 and FAA/RD-90/9. The FAA anticipate that heliport/vertiport designers will take these three documents into consideration in the design process. In so doing, we expect that they will avoid by design potentially hazardous situations. This third document is intended primarily for use by heliport/vertiport designers and operators, primarily as a teaching document. However, pilots may also find it of interest as a way to become more aware of the types of accidents and incidents taking place at landing sites and how they can be avoided.

2.4.3 Rotorwash Accident/Incident Analysis. The FAA has analyzed a number of accidents and incidents that appear to have been caused by rotorwash. The model described in FAA/RD-90/25 has been used to identify threshold levels where rotorwash becomes potentially hazardous. This effort is documented in report FAA/RD-90/17, Analysis of Rotorwash Mishaps. (See section 2.3 for additional discussion on this effort.)

2.4.4 Summary - Helicopter Accident/Incident Analysis. One of the more objective ways to determine if things are going well is to look at accident rates and the data on individual accidents and incidents. Helicopter accident rates have improved dramatically over the last several decades. These rates have improved to the point where continued improvements are increasingly difficult and increasingly expensive to achieve.

And yet, improvement must continue because the US public demands that all facets of the aviation industry must show continual

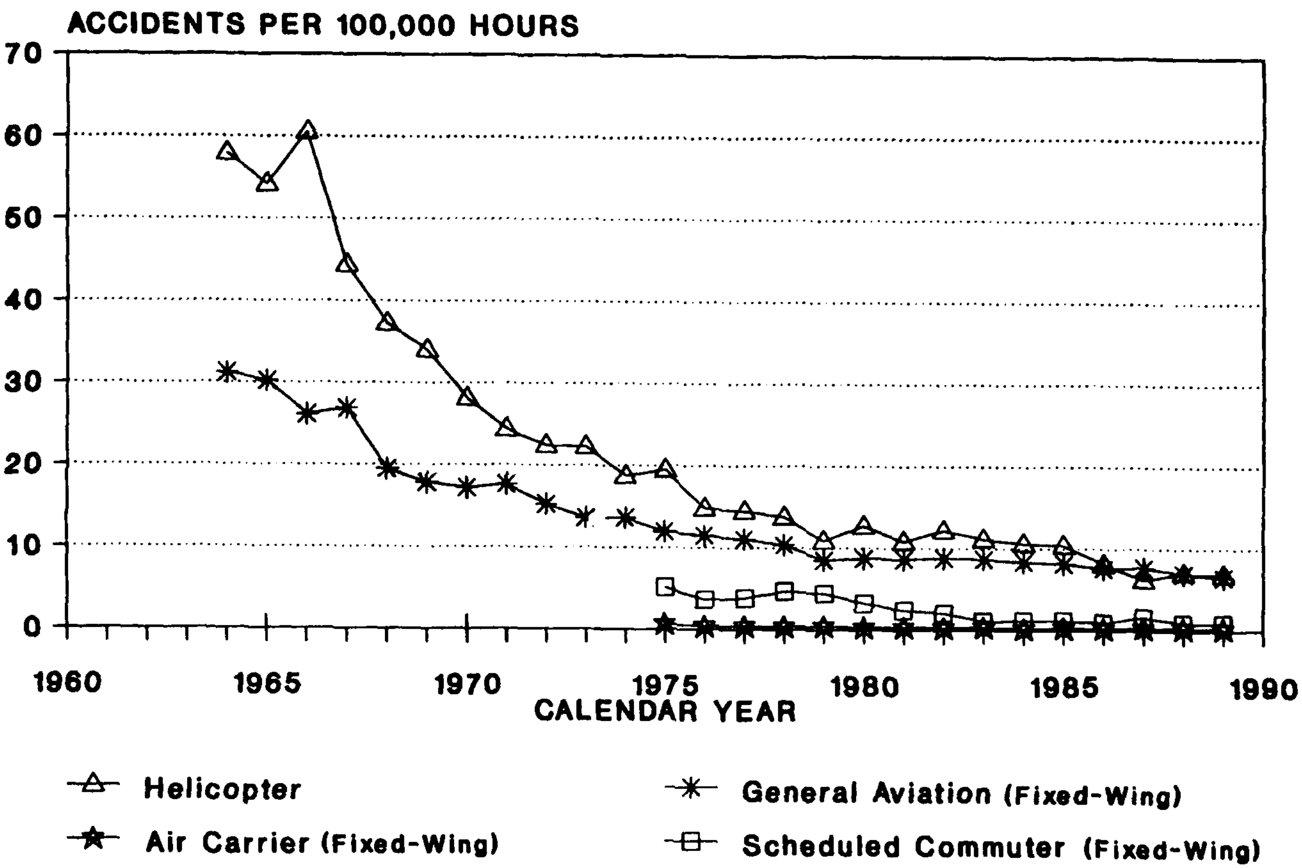


Figure 7. Annual Accident Rates

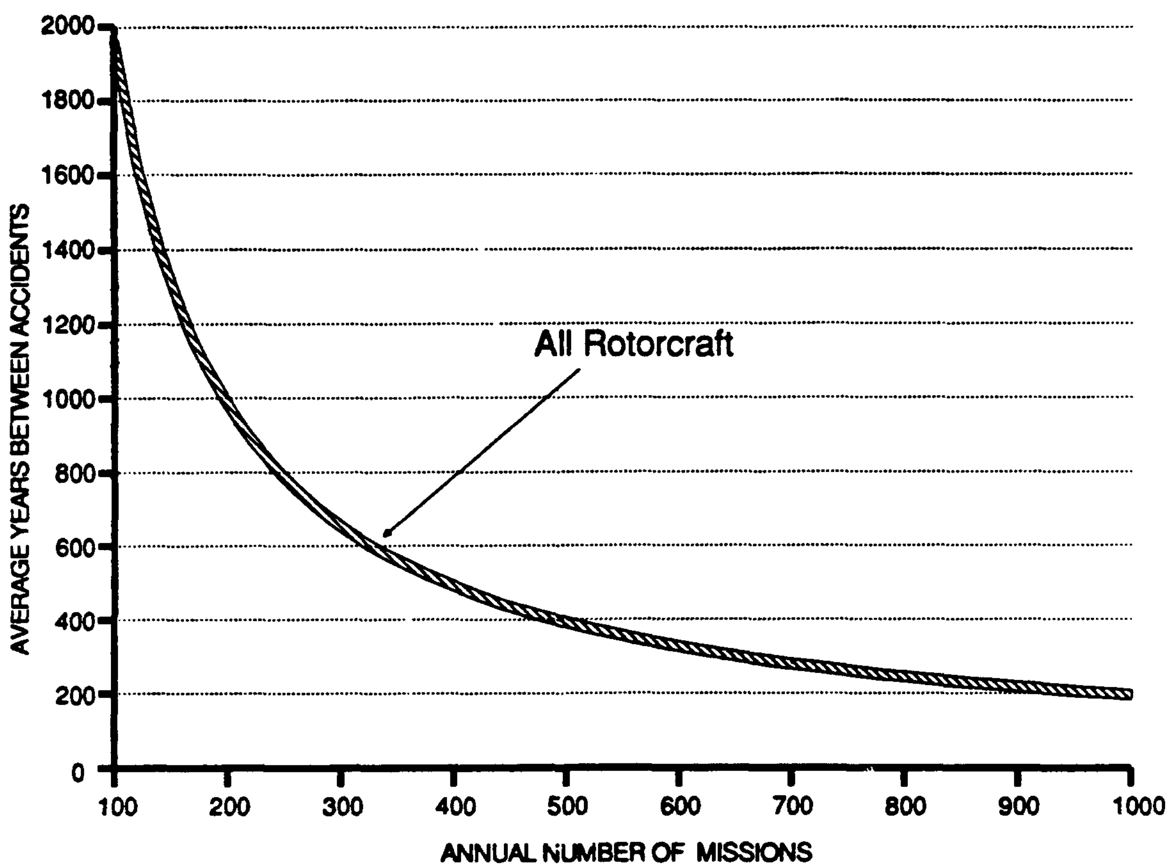


Figure 8. Neighborhood Risk Exposure

improvements in their accident rates (see discussion in section 6.0, Safety Perspective). The rotorcraft community can ill afford the bad publicity that would come from failure to make such improvements. Some of these improvements can be accomplished with better training and better operational constraints at heliports. Some improvement can be accomplished via changes in the heliport design criteria, and great improvements can be accomplished by striving to bring a larger number of heliports into full compliance with the standards and recommendations of the Heliport Design AC. All of these improvements will be required if we, the rotorcraft community, are to continue to improve our accident rates.

Helicopter accident/incident analysis is one of the more objective ways to determine if things are going well on a specific safety issue. It is not, however the only way and it should not be used as a litmus test for all proposed changes. The world changes constantly and aviation is a segment that changes more rapidly than many others. In the midst of change, it is appropriate to anticipate future problems and to solve them before they lead to significant numbers of accidents. Bear in mind that aviation accidents are rare events. Thus, an unsafe situation may exist for a long time before it is highlighted by a statistically significant number of related accidents and incidents. The absence or sparsity of a particular type of reported accident/incident may effect the benefit/cost ratio of proposed solutions but it does not necessarily mean that the current circumstances provide a high level of safety.

2.4.5 Future Work - Vertical Flight Accident/Incident Analysis. Among the areas that need to be pursued in future work are the following:

a. Develop safety programs to assist in reducing accident rates in those portions of the rotorcraft industry with the highest accident rates.

b. Look at those portions of the rotorcraft industry where dramatic reductions in accident rates have been accomplished. Study how these improvements have been accomplished and what they are doing to continue to keep the rates low. Encourage other portions of the industry to adopt similar practices.

c. Initiate a detailed study of heliport and airport obstruction markings in order to develop ways to reduce the number of collisions with such obstacles.

d. Undertaking a long-term rotorcraft accident analysis to examine individual accidents of various types as they occur. This would be done while it is still possible to obtain additional data to supplement that collected by NTSB. This would allow us to answer questions that currently can not be

answered due to a lack of certain detailed data in the accident records. The FAA should seek industry input on the types of accidents to be studied in depth and the specific questions this study ought to be addressing.

e. Compare the accident rates of the various rotorcraft missions with the comparable fixed-wing mission (eg., the rotorcraft corporate/executive accident rate versus the fixed-wing corporate/executive accident rate). In missions where the rotorcraft accident rate is significantly higher than the comparable fixed-wing accident rate, study to determine why ths is the case and look for opportunities and ideas that could reduce the rotorcraft accident rate.

2.5 Heliport/Vertiport Marking Symbols.

2.5.1 Heliport TLOF Marking Symbols - Requirements. In the mid-1960's, the FAA and the U.S. Army developed a standard heliport marking symbol. This effort started with an examination of the current practices, discussions with helicopter pilots, and the development of a list of fundamental requirements for a marking symbol. On a consensus basis, the FAA and industry concluded that the heliport marking symbol should provide the following guidance to the pilot during an approach:

a. identification of a heliport site from a minimum distance of one mile (1.6 km), measured on the ground, at viewing angles from 5 to 20 degrees inclusive under VFR conditions.

b. a means of directional control to the pilot during the approach to the helipad.

c. a field of reference to assist the pilot in maintaining the correct attitude of the helicopter during the approach to the helipad.

d. assistance to the pilot in controlling the rate of closure to the helipad.

e. a point of convergence to the desired touchdown or hover area.

f. assistance to the pilot in determining the location of the helicopter with respect to the touchdown or hover point when the helicopter is directly over the helipad.

2.5.2 Heliport TLOF Marking Symbols - Testing and Results. Once the list of section 2.5.1 was accepted as a desirable list of characteristics, various marking patterns were tested to determine how well they could meet these requirements. Following laboratory testing and scale-model studies, flight test evaluation was conducted. Results are documented in the 1967

report TR 4-67, Development Study for a Helipad Standard Marking Pattern.

In the scale model laboratory testing, 25 patterns were evaluated. These patterns are shown in Figure 9, Marking Patterns Evaluated by Preliminary Tests (taken from report TR 4-67). Among the patterns considered and rejected was the "triangle H" pattern then in wide use by industry. (Due to "the congestion and compactness of the pattern," it "lost its identity" from some viewing angles.) From the initial model tests, 9 patterns were selected for further scale evaluation. These patterns are shown in Figure 10, Marking Patterns Evaluated by Final Model Tests (taken from report TR 4-67). Of these 9 patterns, 2 patterns were eliminated because they were not identifiable at the shallow approach angles. (One of the patterns eliminated was a modified version of the "triangle H". The other pattern eliminated was a "circle H".) The remaining seven patterns became candidates for flight testing.

Among the conclusions of the laboratory testing are the following:

a. A minimum pattern size of 75 feet is needed to be identifiable from a distance of one mile at a viewing angle of 5 degrees.

b. Pattern identification works best when the pattern is between 50 and 83 percent of the size of the helipad. (Smaller patterns tend to disappear. Larger patterns tend to blend with the edge markings.)

c. A ratio of line width to pattern size of 0.07 provides the best pattern definition. (Narrower lines tend to disappear. Wider lines tend to give the impression that the entire pad is painted.)

The initial flight tests were conducted at Fort Rucker, Alabama. "Pattern F" (Maltese Cross) "was the first choice by a great majority". "Pattern B" ("broken-wheel") was a respectable second choice. The remaining patterns trailed far behind.

Further flight testing was conducted at Fort Wolters, Texas. Both instructors and student pilots felt that the markings improved their approach performance. The performance-improvement scores were about equal for the two markings. However, for both instructors and student pilots, the preference scores were higher for the Maltese Cross.

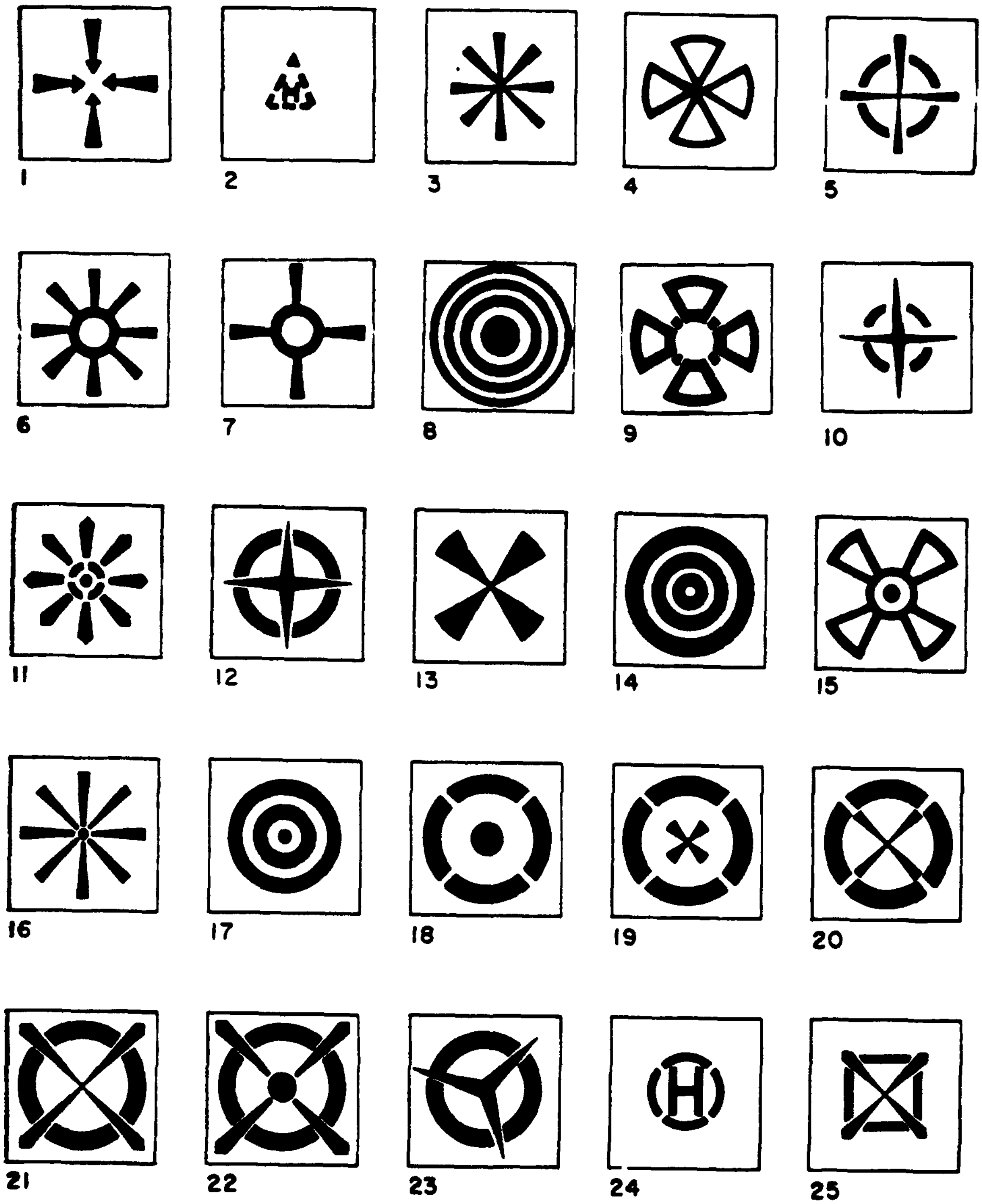


Figure 9. Marking Patterns Evaluated by Preliminary Tests

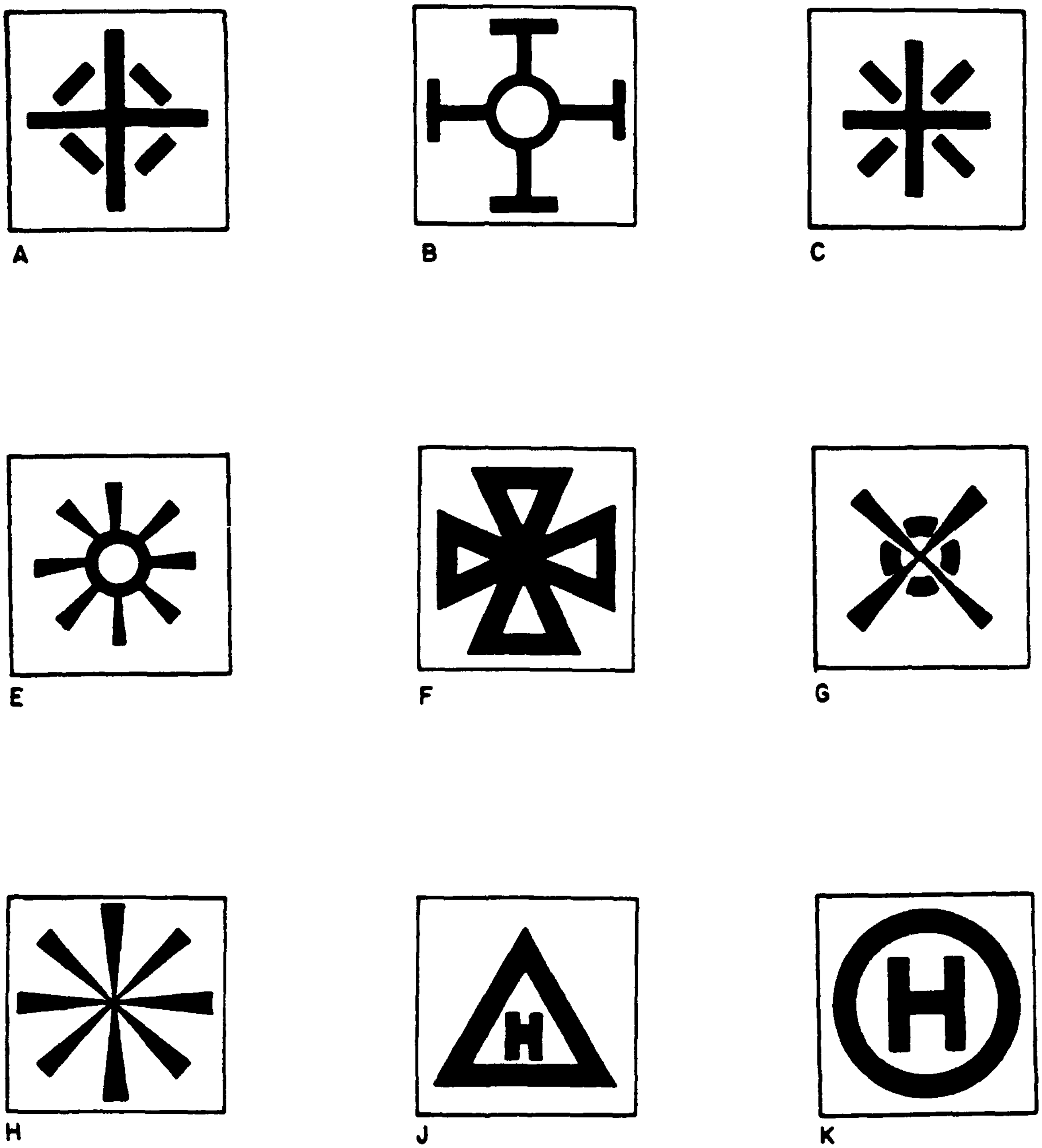


Figure 10. Marking Patterns Evaluated by Final Model Tests

The Maltese Cross was selected as the standard heliport marking pattern by the Army (for military heliports) and by the FAA (for civil heliports). In the late 1970's, however, the FAA Administrator repealed this standard when it was charged that the Maltese Cross was anti-semitic. At this point, it would have been logical to adopted "Pattern B" ("broken-wheel") as the standard marking. Apparently, however, this was not considered. In the 1977 Heliport Design Guide AC, the "triangle H" was recommended as the standard heliport marking symbol even though prior testing had shown that it had serious shortcomings.

By the time the 1988 Heliport Design AC was published, the shortcomings of the "triangle H" had been widely recognized and the large "H" became the recommended marking for public heliports. (The large "H" had not been one of the symbols tested in the mid-1960's.) Unfortunately, however, the 1988 Heliport Design AC also stated: "any recognizable letter, logo, initial, symbol, etc., may be used to identify the heliport." People had lost sight of the impressive list of requirements that were satisfied by a standard heliport marking pattern. While the use of personal initials or a company logo may provide some ego satisfaction, this is accomplished at the price of a decrease in heliport safety.

During the revision of the 1988 Heliport Design AC, industry argued that personal initials or a company logo provide a safety benefit by specifically identify a particular helipad. While this is true, there are other ways to achieve this benefit without giving up the benefits of the standard heliport marking symbol. For example, the company logo could be located adjacent to the helipad on the ground or on the roof of a building.

2.5.3 Vertiport TLOF Marking Symbol. In the late 1980's, the FAA developed a Vertiport Design Advisory Circular designated as AC 150/5390-3. Part of this effort addressed the issue of a vertiport marking symbol. Among the symbols considered were the standard "H", a large capital "V", and "VTOL." Opinions differed as to whether the vertiport marking symbol should differ from the heliport marking symbol. Initially, "VTOL" was selected as the standard vertiport symbol. However, when the FAA Technical Center Heliport was marked with this symbol, both FAA and industry pilots concluded that this pattern did not work very well. This lead the FAA and industry to reopen this issue.

In reconsidering this issue, the FAA revisited the 1967 report TR 4-67, Development Study for a Helipad Standard Marking Pattern. Discussions with industry confirmed that the list of desirable characteristics for a heliport marking symbol were also appropriate for a vertiport marking symbol. No additions or deletions were recommended to the list of desirable characteristics shown in section 2.5.1.

In their discussions of candidate vertiport symbols, the FAA and industry again considered and rejected the standard "H" and the Maltese Cross. The symbol selected as the standard Vertiport marking pattern was "Pattern B" (broken-wheel). This symbol is recommended in the 1990 Vertiport Design AC. At the time that this decision was made, there was some discussion about adopting this symbol as the standard for heliports as well. The working group decided that such a decision was premature. They concluded that this issue should be revisited when the rotorcraft community has had sufficient experience with the "broken-wheel" symbol.

2.5.4 Summary - Heliport/Vertiport Marking Symbols. As a safety aid, the heliport and vertiport marking symbols can be more useful than what is generally recognized. A properly chosen symbol can satisfy an impressive list of requirements (see section 2.5.1), each of which constitutes a type of assistance to the pilot during the approach. Such assistance provides for a safer approach. Consequently, standard marking symbols should be used at both public and private heliports and vertiports. Few safety aids are more cost effective than the use of this little bit of reflective paint.

The use of personal initials or a company logo may provide some ego satisfaction but this is accomplished at the price of a decrease in heliport safety. Such non-standard symbols should be discouraged.

Heliport designers and operators would do well to review the conclusions of section 2.5.2 and adjust the size and type of symbol that marks their heliport accordingly.

Several states have developed requirements for heliport markings. As an example, one state requires all private heliports to be marked with the letters PVT. Since virtually all the heliports in the state are private, the number of heliports with this marking is large. While markings such as this may serve a purpose, they can result in visual clutter and detract from the purpose of a standard marking symbol, decreasing the safety of the facility in the process.

Heliport designers and operators would do well to review their facilities from this perspective and eliminate unnecessary visual clutter in their markings of the final approach and takeoff area (FATO). State aviation authorities would do well to reconsider their heliport marking requirements in light of the results documented in the 1967 report TR 4-67, Development Study for a Helipad Standard Marking Pattern.

2.6 Other Design Issues.

2.6.1 Nonprecision Approach Airspace. In the 1990 Vertiport Design AC, the minimum obstacle-free airspace required for a nonprecision approach is substantially larger than that defined

by the 1988 Heliport Design AC. The larger airspace in the Vertiport Design AC reflects a reexamination, by the FAA, of the limited accuracy of the various systems that could deliver a pilot to the missed approach point on a nonprecision approach to a vertiport. The same systems may also deliver pilots to the missed approach point on a nonprecision approach to a heliport. Thus, the minimum required airspace for a heliport nonprecision approach needed to be modified. Such changes are reflected in the 1994 Heliport Design AC.

At the time that the 1994 AC was finalized, heliport GPS TERPS work was underway. When this work is completed, it is quite likely that the minimum airspace requirements for a nonprecision GPS approach to a heliport will differ somewhat from the generic nonprecision approach airspace shown in the 1994 AC. Thus, it may be appropriate to modify the 1994 AC with the addition of the minimum required GPS nonprecision airspace. (Note: The develoment of GPS Category 1 precision approach TERPS is currently in the planning stages.) It would also be appropriate to modify FAR 77 since the section on heliports currently makes no mention of IFR airspace.

In a recent benefit/cost analysis, the FAA objective was to determine if there is an economic basis for improvement of these low altitude instrument flight rules (IFR) services within the National Airspace System (NAS) in order to better support rotorcraft IFR operations. (See Section 5.0 for more information on this three volume set of reports: FAA/DS-98/9, FAA/DS-89/10, and FAA/DS-89/11.) In view of the benefits of nonprecision approaches, planners should strive to ensure that the majority of all new landing facilities have the ground area and airspace to support nonprecision operations even if they don't expect to provide such services immediately. This is particularly the case for hospital heliports.

2.6.2 Magnetic Interference to Avionics. This section discusses magnetic interference from a variety of sources including magnetic resonance imagers (MRI's), a superconducting magnetic energy storage unit (SMES), and from sources such as elevator motors.

The MRI is a fairly recent medical device. It uses an intense magnetic field and radio frequency energy to produce detailed images of human soft tissue. The medical value of these machines is unquestioned. However, in recent years there have been numerous incidents where MRI's have interfered with the operation of EMS helicopter magnetic compasses and directional gyroscopes and caused these magnetic instruments to give false readings with large azimuthal errors. These effects have appeared to be temporary and, to date, no mishaps or accidents have been attributed to such interference. However, there is a concern that an accident might result from these temporary effects.

At the present time, there appear to be no effective regulations on the location, design, and use of MRI's with regard to their potential **magnetic** interference. This is an issue of particular concern when the MRI is a portable facility (and therefore lightly shielded or unshielded) facility. (Example: an MRI located in a trailer to allow ready movement between hospitals.)

The FAA investigated the potential hazards of MRI's to helicopter avionics. The following is a concise statement of our findings:

a. The main hazard from MRI fringe fields is that they can cause magnetic sensors to give aberrant readings. These fields are strong enough to influence magnetic sensors (compasses and flux gates) on a helicopter out to a distance of 500 feet from the center of the MRI magnet. As long as the pilot is aware of the possibility of anomalous readings, this should not constitute a hazard for VFR flights. However, under IFR flight, anomalous readings could lead a pilot into unprotected airspace and collision with an obstacle. For this reason, the allowable strength of MRI fringe fields must be limited to 0.005 Gauss if IFR operations are to be conducted at the hospital heliport.

b. Fringe fields from an MRI are strong enough to influence cathode ray tubes and night vision goggles. Although no occurrences of distortion on such helicopter avionics have been documented, EMS operators and the FAA should consider this effect when considering operations near MRI's.

c. Maintaining adequate separation from MRI magnets is the most effective means of avoiding adverse effects of MRI's on helicopter systems. To preclude such effects at an IFR heliport, the FATO and the edges of the approach/departure surface(s) should be geographically separated from the MRI. A separation of 500 feet will preclude interference from a powerful, unshielded MRI. For less powerful and/or shielded MRI's, the heliport FATO or the edges of the approach/departure surface(s) should not be within the 0.005 Gauss line of the MRI.

d. Vigilance of flight crews, helicopter operators, and hospital administrators is required to minimize potential hazards from MRI fringe fields. Cooperation among all three groups is necessary to ensure that a helicopter is never inadvertently exposed to a fringe field.

e. Most MRI's operate continually because of the high cost of shutting them down. Pilots should never assume that an MRI has been shut off. Rather, they should assume that the magnetic fringe field is always present and that the fringe field will affect magnetic sensors.

f. Heliport owners and users should take steps to make pilots aware of the locations of MRI's and their potential safety hazards. In addition, signs should be posted in the vicinity of the heliport to alert pilots of the nearby presence of an MRI.

MRI magnetic interference is discussed in FAA/RD-92/15, Potential Hazards of Magnetic Resonance Imagers to Emergency Medical Service Helicopter Operations. This document focused on VFR heliports. At IFR heliports, azimuthal errors of magnetic compasses and directional gyroscopes are considerably more serious. With the advent of GPS, a significant number of heliports, particularly hospital heliports, are likely to seek instrument approach procedures. The FAA is considering whether additional study is required on the potential impact an MRI could have on instrument operations at IFR heliports.

There are other very strong magnetic devices being developed, some that are considerably more powerful than the typical MRI. One such device, a superconducting magnetic energy storage unit (SMES), is being developed by the Army Corps of Engineers and the Department of Energy. While the FAA MRI research effort did not specifically address the SMES, it is likely that the results will be helpful in considering the environmental impact of the SMES and other very powerful magnetic devices.

Both MRI's and SMES are high power magnets that can cause magnetic interference out to considerable distances. Industry has reported azimuthal errors of 60 degrees from low power magnetic devices such as elevator motors. Unlike MRI's, only a modest investment is required to mitigate such interference by shielding the elevator motors. In FAA/RD-92/15, simple procedures for determining the presence of magnetic interference at a heliport site will work equally well regardless of whether the source of the interference is an MRI, an elevator motor, or some other source.

2.6.3 Public Versus Private Heliports. The 1988 FAA Heliport Design AC specified a large number of requirements for public heliports. For private heliports, only a small number of requirements were specified in the 1988 AC. Among the significant issues not specifically addressed were minimum required approach and departure airspace, minimum required size of parking areas, and minimum size of taxiways. In addition, on other issues specifically addressed, the recommendations for private heliports were less demanding than those for public heliports. (Example: Flags can be used instead of wind socks.) In the 1992 Heliport Design AC, this philosophy has not changed significantly.

There are two reasons frequently given to justify the absence of specific minimum requirements on these issues for private heliports:

a. Operators of private heliports can control several factors that can not be controlled by operators of public heliports. The controllable factors include what specific helicopters operate at the heliport, what pilots operate there, the training and currency of these pilots, and the operations they conduct in the vicinity of the heliport. In controlling these factors, it is argued, private heliport operators can achieve the same level of safety as public heliports.

In looking at private heliports and their operations, some operators are controlling these factors to achieve a higher safety level. However, it appears that many operators are not choosing to design and operate private heliports in a way that achieves the same level of safety as is available at public facilities designed according to the Heliport Design AC. Perhaps some operators have a limited awareness of what can and should be done to achieve a higher level of safety at a private heliport.

b. Operators of private heliports can choose to operate at a lower level of safety than what is appropriate for public facilities.

With automobiles, some people choose to drive large crashworthy vehicles with airbags, anti-lock brakes, and seat belts buckled. Other people choose to drive very small vehicles with minimum safety features and seat belts unbuckled. Private heliport operators can make similar choices and many appear to have done so, either consciously or unconsciously. This tends to lead to a higher number of accidents and the negative public relations that accidents entail. Safety concerns are one of several issues cited by people opposing new heliports. (It should be noted that helicopter accident data do not support these fears (see FAA/RD-90/9).)

Based on the analysis documented in report FAA/RD-90/8, it is clear that many helicopter landing site accidents and incidents could be avoided if the facilities were designed or upgraded to meet the FAA Heliport Design Advisory Circular recommendations for public heliports. This is a safety/economic issue that needs to be addressed.

This issue is of particular concern with regard to hospital heliports. Hospital heliports are not public facilities in the sense that they are not available for use by all helicopters without prior approval. However, they are "public" facilities in the sense that virtually anyone could find themself a passenger of an emergency medical services (EMS) helicopter flying into such a heliport. Thus, one could argue that hospital heliports have an obligation to provide the same target level of safety as public heliports. This would require that they meet the same

design standards. An added advantage of being a public facility is that it affords the heliport some protection under FAR 77, Objects Affecting Navigable Airspace.

In the 1994 Heliport Design AC, a chapter has been added on hospital heliports. The philosophy behind this chapter is that the minimum requirements for hospital heliports are more demanding than private heliports but less demanding than public heliports. Recognizing that almost all hospital heliports are private facilities, the 1994 AC recommendations for hospital heliports are more demanding than what was recommended in the 1988 AC. However, industry has not accepted the argument that a hospital heliport should meet the same requirements as a public heliport.

3.0 <u>VERTICAL FLIGHT LANDING SITE DESIGN AND PLANNING - PUBLISHED REPORTS</u>. This is a list of published FAA technical reports of particular interest to heliport/vertiport planners and designers. Reports are listed in chronological order by report number. All of these published reports are available from AHS and HAI. For those reports that are available from NTIS, the NTIS accession number is shown in parentheses.

TR 4-67 (1967), Development Study for a Helipad Standard Marking Pattern. (Not available from NTIS) The objective of this study was to determine the marking pattern that would best fulfill requirements established on the basis of then current practices, discussions with helicopter pilots, and objective testing. Requirements/advantages of a heliport marking pattern included such issues as providing:

a. identification of a heliport site from a minimum distance of one mile (1.6 km), measured on the ground, at viewing angles from 5 to 20 degrees inclusive under VFR conditions.

b. directional control to the pilot during the approach to the helipad

c. a field of reference to assist the pilot in maintaining the correct attitude of the helicopter during the approach to the helipad

d. assistance to the pilot in controlling the rate of closure to the helipad

e. a point of convergence to the desired touchdown or hover area

f. assistance to the pilot in determining the location of the helicopter with respect to the touchdown or hover point when the helicopter is directly over the helipad.

Field tests were conducted following laboratory observations and scale-model studies. (See section 2.5 for additional discussion on this topic.)

FAA/PM-84/22, Heliport Snow and Ice Control Methods and Guidelines. (NTIS: AD-A148137) These guidelines provide a methodology to assist heliport planners and designers with the selection of the most appropriate snow and ice control method. The guidelines consider manual methods of snow and ice control such as shovels/plowing and chemical application, and automated methods such as pavement heating systems.

FAA/PM-84/23, Structural Design Guidelines for Heliports. (NTIS: AD-A148967) Structural design guidelines for heliports are analyzed using data obtained from literature and from surveys of helicopter manufacturers, helicopter design consultants, and helicopter operators. Primary topics of interest are the loads on heliport structures caused by helicopter hard landings, rotorwash, and helicopter vibrations. Guidelines for appropriate load combinations for heliport structural design are also presented. This document could be useful in the design of rooftop heliports.

FAA/PM-84/25, Evaluating Wind Flow Around Buildings on Heliport Placement. (NTIS: AD-A153512) Descriptions and illustrations of wind flow patterns and characteristics for both isolated and multiple building configurations are provided to assist heliport planners, operators, and helicopter pilots in understanding the problems associated with building-induced winds. Based on geometric flow patterns, general guidelines for ground level and rooftop heliport placement are provided. This document would also be useful as an aid in choosing the location of a windsock.

Recent rotorcraft accident analyses (FAA/RD-90/8) indicates that the vertical flight community could prevent a number of rotorcraft accidents at landing sites by paying more attention to issues involving wind flow. This document would also be useful in evaluating the effect that a proposed building would have on operations at a particular landing site.

FAA/PM-86/28, Investigation of Hazards of Helicopter Operations and Root Causes of Helicopter Accidents. (NTIS: AD-A171994) The acid test of whether the vertical flight community is doing things correctly is in the daily operations. The accident records can tell us when we have failed this test and where we need to improve. This report documents a broad investigation of helicopter accidents. Based in part on the results of this effort, the FAA has conducted several other rotorcraft accident analyses. Each analysis focused on specific subsets of accidents. One of them looked specifically at heliport accidents and incidents (FAA/RD-90/8, FAA/RD-90/9, FAA/RD-91/1). A second effort looked at accidents involving rotorwash (FAA/RD-90/17). Each of these reports is discussed briefly later in this section. (See section 2.4 for a more detailed discussion.)

FAA/PM-86/30, The Siting, Installation, and Operational Suitability of the Automated Weather Observing System (AWOS) at Heliports. (NTIS: AD-A175232) This document provides the basis for FAA recommendations on the installation and siting of AWOS at heliports. This document would be of interest to anyone considering the installation of an AWOS at a heliport. Also of interest are AC150/5220-16A, Automated Weather Observing Systems (AWOS) for Non-Federal Applications and FAA Order 6560.20A, Siting Criteria for Automated Weather Observing Systems (AWOS).

FAA/CT-TN87/4, Simulation Tests of Proposed Instrument Approach Lighting Systems for Heliport Operations. (Not available from NTIS) This report documents some of the testing done to develop the configuration of the heliport approach light system (HALS). This testing made use of a terrain board as the principal part of the simulation. Other documents in this list address flight testing of HALS (see reports FAA/CT-TN89/21 and FAA/CT-TN89/14).

FAA/PM-87/31, Analysis of Heliport System Plans. (NTIS: AD-A195283) This study analyzed the strengths and weaknesses of four state and four metropolitan heliport system plans. Planning concepts are identified and defined to include:

a. baseline parameters for evaluating the plans,
b. identifying the data (and their sources) needed for planning purposes at any jurisdictional level, and
c. developing criteria for assessing the feasibility and economic viability of proposed heliport facilities.

(The four state plans reviewed were Michigan, New Jersey, Louisiana, and Ohio. The four metropolitan plans reviewed were Pittsburgh, Phoenix, Houston, and Washington, DC.)

FAA/PM-87/32, Four Urban Heliport Case Studies. (NTIS: AD-A195284) This study developed case histories of four heliports built in the central business districts of major cities. (The heliports studied were the Bank-Whitmore Heliport (Nashua Street Heliport) in Boston, the Indianapolis Downtown Heliport, the New Orleans Downtown Heliport, and the Western and Southern Heliport in Cincinnati.) The effort identified six essential elements of a successful heliport. Consideration of these elements would aid in the prediction of whether a proposed heliport will succeed or fail. These six elements are

- location
- demand
- local government attitude
- public attitude
- financial backing
- integral planning

FAA/PM-87/33, Heliport System Planning Guidelines. (NTIS: ADA-199081) This report provides recommendations on the necessary content of a state or metropolitan heliport system plan. A subset of this information was formatted into a draft heliport system planning chapter in the FAA advisory circular on state airport system planning. However, since this chapter seven is as large or larger than the remaining six chapters of this AC, the FAA is considering making it a stand-alone advisory circular.

FAA/CT-TN87/40, Heliport Visual Approach and Departure Airspace Tests, Vol. 1 Summary, Vol. 2 Appendixes. Vol. 1: (NTIS: ADA-200028); Vol. 2: (Not available from NTIS) This report contains measured flight data on the airspace consumed during heliport approaches and departures under VFR conditions. Data collection primarily addressed straight-in

approaches and straight-out departures. However, a limited amount of curved approach and departure data were collected and additional collection of such data was recommended.

This testing is part of an effort to determine objectively the minimum airspace required at a VFR heliport. Originally, this effort was started with the expectation that it might provide data supporting a modest decrease in the minimum required airspace for VFR heliports. However, this effort has convincingly shown that no such decrease is appropriate. Rather, results point to a need for a substantial increase in the minimum VFR heliport airspace. The results of this document need to be considered in concert with several other documents, particularly FAA/DS-88/12, FAA/RD-90/4, and FAA/RD-90/9.

FAA/CT-TN87/54, Analysis of Heliport Environmental Data: Indianapolis Heliport, Wall Street Heliport, Vol. 1 Summary, Vol. 2, Wall Street Heliport Data Plots, Vol. 3 Indianapolis Downtown Heliport Data Plots. Vol. 1: (NTIS: AD-A206708); Vol. 2: (NTIS: AD-A212312); Vol. 3: (NTIS: AD-A217412) The measured data in these documents describe the magnitude of the rotorwash generated by different types of helicopters in actual operations. Using these data, the FAA Technical Center has developed computer software that show real time variation in the magnitude and direction of rotorwash during these heliport operations. A separate report documents similar tests at Intracoastal City, Louisiana (FAA/CT-TN89/43). These and other data were used to develop a rotorwash computer model (FAA/RD-93/31). This model has been used as an aid in the analysis of accidents and incidents caused by rotorwash (see report FAA/RD-90/17). This effort is directed at developing guidance on how to prevent such accidents.

[Subsequent testing of wind sensor characteristics (documented in FAA/RD-93/10) has raised questions concerning the accuracy of these data in terms of frequency amplitude, frequency content, and velocity magnitude. The rotorwash data in these documents allow a reasonable comparison between the relative magnitude of the rotorwash characteristics of different helicopters. However, the data in these documents significantly underestimate the severity of the rotorwash phenomenon. See section 2.3.1 for a more complete explanation.]

FAA/EE-88-2, Heliport Noise Model (HNM) Version 1 User's Manual. (NTIS: AD-A219555) The Heliport Noise Model is a computer tool for determining the total impact of helicopter noise at and around heliports. The model runs on IBM PC/XT/AT personal computers and other compatible computers. This manual contains a general description of elements of a heliport noise case study and specific instructions for preparing the case for input.

Currently, this heliport noise model is being revised and improvements are being made to the user interface. In addition, changes are being made to the method for calculating helicopter noise during taxi operations. No release date has been announced.

FAA/DS-88/12, Minimum Required Heliport Airspace Under Visual Flight Rules. (NTIS: AD-A201433) This report is part of an effort to determine objectively the minimum airspace required at VFR heliports. Industry has recommended that the FAA strive to be less subjective and more quantitative with regard to issues on heliport design. FAA testing has been conducted or is underway in several areas in response to this recommendation. A key element in making effective use of such quantitative data is the determination of objective criteria for safety. This report discusses one method for developing such a basis: "target level of safety" (TLOS). Pursuing this topic, report FAA/RD-90/9 documents a helicopter safety study and develops a TLOS for approach/departure operations and a TLOS for ground maneuvering operations.

FAA/CT-TN88/30, Heliport Surface Maneuvering Test Results. (NTIS: AD-A214116) Minimum dimensions requirements for heliport parking areas have been a topic of discussion for a long time. In the mid-1980's, industry recommended that the FAA approach this issue in a way that is more quantitative and less subjective than what has been done in the past. This report is part of the FAA's effort to respond to this recommendation.

This report documents two ways of approaching this problem. The first involves daylight flight tests of 13 pilots in a UH-1 helicopter. The second involves industry pilot responses to questions on how close to an object they would be comfortable in operating. Both approaches addressed various wind conditions.

At the time the flight testing was done, the UH-1 was a DOD aircraft. (The FAA's S-76 was involved in extensive cockpit modifications and was unavailable for use in these tests.) Consequently, the FAA was contractually limited to the use of subject pilots who were qualified and current in the UH-1 under the military's rules. The subject pilots were either National Guard pilots, FAA test pilots, or both. When interviewed after their flight testing, the majority of these pilots stated that they were comfortable with rotor tip clearances of one third the rotor diameter or less (page 12, table 6). However, during actual flight testing, they were more conservative than their verbal statements. (During actual parking maneuvers, the pilots' actual rotor tip clearances averaged between 1.1 and 1.6 times their stated preference.) Taken at face value, the results of the flight testing would support minimum parking area dimensions that provide a tip clearance between one third and one half of the rotor diameter **for operations during daylight hours.**

Industry pilots in the NY/NJ area, Louisiana, and Texas responded to questions concerning rotor tip clearances. In their responses, these 203 pilots were considerably more conservative than the 13 subject pilots (see pages 36 through 41 in report FAA/CT-TN88/30). Depending on wind conditions and on whether the object was an aircraft or a fixed object, only 19 to 41 percent of these pilots said that they were comfortable with rotor tip clearances of one third rotor diameter. Between 19 and 43 percent said that they were uncomfortable with less than one half rotor diameter tip clearances. Between 5 to 17 percent said that they were uncomfortable with less than a full rotor diameter tip clearance. Taken at face value, the results of the industry pilot questionnaires would support minimum parking area dimensions that provide a minimum tip clearance of one full rotor diameter for air taxi maneuvers during daylight hours.

Initially, it appeared that the results of the flight testing (section 2.2.3) and the results of the subjective industry pilots survey (sections 2.2.1 and 2.2.2) were in conflict. This, coupled with certain questions from industry, led the FAA to reexamine these data.

It has long been assumed that tip clearances required for safe ground operations are **directly** proportional to the size of the rotor diameter. However, subsequent analysis of the survey data initially suggested that the relationship might be **indirectly** proportional (see Appendix B). As the rotors get smaller, industry pilots expressed a need for a larger tip clearance. These results compare well with the flight testing of section 2.2.2 since this work was done in a helicopter with a rotor diameter of 48 feet. The FAA has completed similar testing with a Robinson R-22 helicopter (rotor diameter: 25.2 feet). Results are documented in FAA/CT-TN93/6, Combined 1991 and 1992 Robinson - 22B (R-22) Parking Test Results. These results would suggest that minimum tip clearance requirements are relatively constant as a function of rotor diameter. (See section 2.2.6 and Appendix B for more discussion on this topic.)

FAA/CT-TN88/45 Heliport Night Parking Area Criteria Test Plan. (NTIS: AD-A208401) This is the plan used to test heliport parking separations at night under various wind conditions. This effort was similar to a portion of the day time test effort documented in FAA/CT-TN88/30, Heliport Surface Maneuvering Test Results. Results are published in FAA/CT-TN92/1, Helicopter Nighttime Parking Test Results - UH-1.

FAA/DS-89/9, Rotorcraft Low Altitude CNS Benefit/Cost Analysis, Rotorcraft Operations Data. (NTIS: AD-A214113) This is the first of a three volume set of documents. The objective of this study is to determine if there is an economic basis for improvement of low altitude instrument flight rules (IFR) services within the National Airspace System (NAS) in order to better support rotorcraft IFR operations. This first report

provides background data on the rotorcraft industry as well as forecasts to the year 2007 for the purpose of providing operational data for analyses of long-term benefits and costs. It describes rotorcraft missions, selects those most likely to benefit from increased availability of IFR services, identifies the probability of various ceiling and visibility combinations within selected rotorcraft operating areas, and presents an inventory of rotorcraft activity by mission and location. While this first report does not deal specifically with heliports/vertiports, it contains a wealth of data that heliport/vertiport planners may find of interest.

FAA/DS-89/10, Rotorcraft Low Altitude IFR Benefit/Cost Analysis: Operational Analysis. (NTIS: AD-A246865) This is the second of a three volume set of documents. This second report defines operational requirements and constraints for selected rotorcraft missions. A candidate list of 50 sites around the country, selected for their potential to benefit from increased low altitude IFR services, is presented. Radar and communications coverage in those areas are then identified. CNS improvements to be provided by implementation of the NAS plan, relevant FAA policies, ATC procedures, and avionics improvements are analyzed for their potential to benefit low altitude rotorcraft IFR operations. Finally, a benefit/cost methodology to determine where the most benefits would accrue from improvements in rotorcraft low altitude IFR services or changes in ATC procedures is presented.

FAA/DS-89/11, Rotorcraft Low Altitude IFR Benefit/Cost Analysis: Methodology and Application. (NTIS: AD-A274241) This is the third of a three volume set of documents. This final report reviews the operational requirements and constraints for specific rotorcraft missions identified in the previous reports in this series. It also reviews all of the alternatives identified for improving rotorcraft operations. The alternatives considered include nonprecision approaches to heliports, additional communications and surveillance equipment, and air traffic control procedural changes. A benefit/cost analysis is conducted for each nonprecision approach, communication, surveillance, and procedural improvement identified. Heliport/vertiport planners may find the information on nonprecision approaches of particular interest. In view of the benefits of nonprecision approaches, planners would be well advised to ensure that the majority of all new landing facilities have the ground area and airspace to support nonprecision operations even if they don't expect to provide such services immediately.

FAA/CT-TN89/21, Helicopter Visual Segment Approach Lighting System (HALS) Test Report. (NTIS: AD-A214085) This report documents flight testing of the heliport approach light system (HALS). The HALS works very well in support of MLS precision approaches in an environment relatively devoid of city lights. In the absence of the HALS, several pilots were well inside the

Decision Height (DH) when they made decisions to initiate a missed approach. This resulted in flights through airspace that present rules do not require to be obstacle free. Additional testing is planned to determine the appropriate weather minimums for precision approach operations in the absence of a HALS.

The HALS is considerably smaller than runway approach light systems. Nonetheless, it still requires a considerable amount of ground area. The question has been asked: "Will we ever see such a system at any heliport other than the FAA Technical Center?" The FAA is fully aware that heliports that have the area for a HALS generally don't have the operations to justify a MLS precision approach, primarily due to the expense of the MLS ground system. In addition, heliports with the operations to support a precision approach generally do not have the ground area that a HALS would require. (When GPS and/or LORAN-C instrument approaches are readily available at heliports, the cost to obtain a commissioned instrument approach procedure will be considerably less. The substantial cost reduction could lead to the installation of a number of approach lighting systems at heliports.)

The FAA looks at lighting as one alternative for ensuring the safe operation of rotorcraft under lower minimums than what would otherwise be possible. In the near to mid-term, the number of heliports/vertiports that will install such a system may be small. However, the more alternatives available, the better the position the industry will be in to pick the combination of alternatives that make sense for each application of interest. As other alternatives become apparent, the FAA will consider testing them to see what they offer the industry in terms of operational benefits.

FAA/DS-89/32, Indianapolis Downtown Heliport - Operations Analysis and Marketing History. (NTIS: AD-A222121) This report documents a detailed analysis of the numbers and types of operations at the Indianapolis Downtown Heliport from its opening in 1985 through March 1989. It also discusses the marketing techniques used during the planning and development stages of the heliport as well as the continuing marketing effort used to retain and increase business. By documenting operations at successful heliports, the FAA anticipates that this will provide heliport planners with information that will better enable them to build successful heliports at other locations.

A similar document (FAA/RD-91/12) has been published on the Downtown Manhattan Heliport (Wall Street).

FAA/CT-TN89/34, Heliport Visual Approach Surface High Temperature and High Altitude. (NTIS: AD-A226542) This report documents the results of the Albuquerque tests defined in FAA/CT-TN88/5, Heliport Visual Approach Surface High Temperature and High Altitude Test Plan. The Albuquerque tests were very similar to

the low altitude tests conducted at the FAA Technical Center and documented in FAA/CT-TN87/40, Heliport Visual Approach and Departure Airspace Tests.

FAA/CT-TN89/43 Analysis of Heliport Environmental Data: Intracoastal City, LA. (NTIS: AD-A228547) This report documents testing similar to what is in FAA/CT-TN87/54, Analysis of Heliport Environmental Data: Indianapolis Heliport, Wall Street Heliport. The data collected at Intracoastal City involved a large number of helicopters, many of which were larger than those seen at other locations where the FAA has collected rotorwash data.

[Subsequent testing of wind sensor characteristics (documented in FAA/RD-93/10) has raised questions concerning the accuracy of these data in terms of frequency amplitude, frequency content, and velocity magnitude. The rotorwash data in these documents allow a reasonable comparison between the relative magnitude of the rotorwash characteristics of different helicopters. However, the data in these documents significantly underestimate the severity of the rotorwash phenomenon. See section 2.3.1 for a more complete explanation.]

FAA/CT-TN89/67, Analysis of Distributions of Visual Meteorological Conditions (VMC) Heliport Data. (NTIS: AD-A221591) This report documents a statistical analysis of VFR heliport approach and departure data contained in FAA/CT-TN87/40, Heliport Visual Approach and Departure Airspace Tests. Analysis shows, in the lateral dimension, the safety margin provided by the 1988 FAA Heliport Design AC recommendations as a function of distance from the helipad. In both the lateral and vertical dimensions, the safety margin provided is inadequate.

This report is part of an effort to determine objectively the minimum airspace required at a VFR heliport. (See discussion in section 2.1.) [There are two versions of this document. The short summary is available from NTIS with the accession number shown above. The long version (1054 pages) is available from the FAA while copies last.]

FAA/RD-90/3, Helicopter Physical and Performance Data. (NTIS: AD-A243805)

FAA/RD-90/4, Heliport VFR Airspace Based on Helicopter Performance. (NTIS: AD-A243739)

FAA/RD-90/5, Operational Survey - VFR Heliport Approaches and Departures. (NTIS: AD-A243804)

These three reports involve an examination of VFR heliport airspace requirements based on helicopter performance capabilities.

Few runways are long enough to handle all airplanes. Few airplanes can land on all runways. An airplane flight manual provides a means to determine the minimum runway length required to takeoff or land. Pilots can easily determine the length of a particular runway because this parameter is well advertized.

With rotorcraft, the corresponding issues are helicopter performance (particularly on departure), acceleration distance, and obstacle-free airspace. Flight manuals of US civil helicopters typically do not describe specific flight performance expected as a function of altitude, temperature, and loading. Thus, in departing on a given day from a given heliport, the pilot does not have the information required to calculate the steepest slope that the helicopter will be able to fly. In addition, the minimum slope that must be flown to avoid the controlling obstacle is not a well advertised heliport parameter. These reports recommend that such information be provided.

For public heliports, where the operators have little or no control over who operates at their facilities, this report indicates the need for additional airspace, particularly for VFR departures. On the other hand, at heliports where the operators can control certain parameters of the helicopter operations that take place, acceptance of the recommendations of these reports could provide some flexibility on the 8:1 slope of the VFR approach/departure paths. (For additional discussion on these reports, see section 2.1.1.2.)

FAA/RD-90/6, Rotorcraft Acceleration and Climb Performance Model. (NTIS: AD-A243737) This report documents the methodology used in developing the helicopter departure profiles presented in FAA/RD-90/3, Helicopter Physical and Performance Data.

FAA/RD-90/7, Helicopter Rejected Takeoff Airspace Requirements. (NTIS: AD-A243738) This report contains an analysis of performance data for helicopters that are certified for Category A operations. It relates rejected takeoff and one engine inoperative (OEI) performance capability to airspace requirements for heliports intended to support Category A operations. Currently, the airspace defined in the Heliport Design AC does not take into account emergency situations involving engine failures during takeoff and landing operations. More specifically, the air and ground space defined in the AC and in 14 CFR Part 77 are inadequate to cover the range of helicopters and conditions that are encountered during rejected takeoff or climbout with one engine inoperative.

The climbout angle requirements in the current AC are too steep for many of the OEI climbout conditions that will be encountered. The climbout angles identified in this study ranged from a high of 20 degrees to a low of 1 degree for helicopters operating with Category A OEI restrictions. The standard 8:1 slope

(7.125 degrees) is too steep for most OEI climbout cases observed in this study.

This report focused on the airspace required for rejected takeoffs by helicopters operating to Category A requirements. This document did not address the issue of when Category A operations should be required.

FAA/RD-90/8, Analysis of Helicopter Mishaps At Heliports, Airports, and Unimproved Sites. (NTIS: AD-A231235) This report documents an analysis of heliport accidents and incidents. (Accident/incident analysis is one of the more objective ways to determine when and where it is necessary to change design standards.) Among the conclusions of this effort are the following:

a. Overall, the 1988 FAA Heliport Design AC provides good guidance.

b. Many of the accidents analyzed might not have occurred if the 1988 Heliport Design AC recommendations had been satisfied at the operating location.

c. A few areas need to be addressed, expanded, or emphasized in the next revision of this AC.

The analysis looked at accidents at 3 types of landing sites: heliports, heliports at airports, and undesignated/unimproved/ remote heliports. At all 3 types of landing sites, a significant percentage of the accidents involved collisions with obstructions. These involved obstruction strikes while ground maneuvering and during approach and departure operations. At airports, the percentage of rotorcraft accidents involving obstruction strikes while ground maneuvering is particularly high.

Based on these results, a number of changes were recommended in the revision of the 1988 Heliport Design advisory circular:

a. Expand Chapter 4 of the 1988 Heliport Design AC substantially to mitigate the high percentage of rotorcraft accidents involving obstruction strikes while ground maneuvering on airports. (Obstruction strikes are the leading cause of helicopter mishaps at airports. The percentage of accidents involving obstruction strikes was nearly five times the percentage of the next largest cause factor.)

b. Add a requirement for marking of obstructions, particularly wires, in the vicinity of the helipad and approach/departure paths. This is needed in order to mitigate accidents involving collisions with obstructions.

c. Increase the requirements for cleared area/airspace for approach/departure paths.

d. Add a requirement for more than one wind indicator at a facility under certain circumstances.

e. Place additional emphasis on heliport surface composition and maintenance.

The results of these recommendations can be seen in the 1994 version of the Heliport Design Advisory Circular. A number of these recommendations were accepted and implemented.

FAA/RD-90/9, Analysis of Rotorcraft Accident Risk Exposure Near Heliports and Airports. (NTIS: AD-A249127) When a heliport is proposed, community objections often focus on the issue of safety and the concern that there is a risk associated with having a heliport as a neighbor. Analysis of accident data shows that heliports are safe neighbors. While people often voice concerns about the possibility of a helicopter accident causing them personal injury or property damage, this document shows that such an event is extremely rare. Heliport proponents may find this document useful as an authoritative reference in responding to community concerns.

At the same time, however, this analysis shows that, during the 1977 - 1986 time period, 34-39 percent of all helicopter accidents occurred at or within one mile of landing sites. Approximately 13-18 percent of all helicopter accidents occurred at or near airports. Approximately 3-5 percent of all helicopter accidents occurred at or near heliports. Approximately 9-18 percent of all helicopter accidents occurred at or near unimproved landing sites. With approximately 3-8 percent of all helicopter accidents, National Transportation Safety Board records do not specify the nature of the landing site.

Clearly, if the rotorcraft community is to continue to reduce its accident rates, reductions must be achieved in the number of accidents taking place at or near landing sites. Such reductions can be achieved through a combination of actions including training, design, operational procedures, etc. This report focuses heavily on what should be done via changes in landing site design standards and guidelines.

This document continues the development of the topic of rotorcraft "target level of safety" first discussed in FAA/DS-88/12, Minimum Required Heliport Airspace Under Visual Flight Rules. In choosing a target level of safety, the FAA and industry would have an objective method for decision making on issues such as the minimum VFR heliport airspace required for curved approaches and departures. This report recommends several target levels of safety on issues of heliport design.

These levels are based on the historical improvement in helicopter accident trends.

FAA/RD-90/10, Rotorcraft Use in Disaster Relief and Mass Casualty Incidents - Case Studies. (NTIS: AD-A229401) This report documents rotorcraft involvement in disaster relief efforts and provides a understanding of the general nature of the rotorcraft portion of such operations. A representative series of 18 case studies detailing disaster situations (i.e., natural disasters, high rise fires, airline crashes, etc.) where rotorcraft have been involved in relief and rescue operations are analyzed. Each case addresses the circumstances of the disaster, the extent of rescue and relief efforts, the nature and extent of prior relief planning, the nature of the actual rotorcraft involvement, the number of people assisted through the application of rotorcraft, the types of landing areas used, and the lessons learned and the post-situation analysis. In these 18 cases, rotorcraft transported approximately 3,357 people and helped to save at least 187 lives.

By addressing cases where rotorcraft have provided life saving services to the local community, this report provides a dramatic answer to the question: "Why should we allow a heliport to be built in our neighborhood?"

FAA/RD-90/11, Guidelines For Integrating Helicopter Assets into Emergency Planning. (NTIS: ADA-241479) In the last four decades, rotorcraft have proven their capability to provide unique assistance in disaster relief operations. Yet both the public and emergency preparedness and disaster relief officials are generally unaware of rotorcraft capabilities and the extensive planning required to enable rotorcraft to assist most effectively. Consequently, they do not take best advantage of the assets (civil and military rotorcraft and the local landing sites) that are available to help deal with a crisis situation.

These guidelines advise how best to integrate rotorcraft into existing disaster relief planning. Advice is given on the inventory of rotorcraft, heliports, participant surveys, rotorcraft dispatch center functions, communications requirements, designation and establishment of landing zones, and plan implementation. This report builds on the case studies contained in report FAA/RD-90/10. Both documents convey the idea that rotorcraft and heliports are valuable community assets, readily available to assist in life saving efforts when needed.

FAA/CT-TN90/12, Evaluation of a Prototype Lighted Ball Marker for Powerline Obstructions. (NTIS: AD-A217746) This project evaluated a prototype powerline obstruction marker. This marker is designed to illuminate when placed on a high voltage (69 KV) powerline. (Power for the illumination is provide by the electromagnetic field generated by the high voltage powerline. No additional wiring is required.) Several of these markers were

flight tested during nighttime VFR conditions. The markers were visible at approximately 4,000 feet under these conditions. Such markings would be useful in areas of rotorcraft activity. In addition, designers may wish to consider the use of such markings if there are high voltage power lines in the vicinity of a heliport or vertiport. (Based on the results of this test, the FAA modified advisory circular AC70/7460-1, Obstruction Marking and Lighting, and recommends the use of such a device as an optional marking device for high voltage power lines.)

FAA/RD-90/16, Evaluation of Rotorwash Characteristics for Tiltrotor and Tiltwing Aircraft in Hovering Flight. (NTIS: AD-A231236) This effort evaluated the rotorwash characteristics of a variety of tiltrotor and tiltwing aircraft. The tiltrotor vehicles included the Bell XV-15, the Bell/Boeing MV-22, the CTR-22A/B, CTR-22C/D, CTR-800, CTR-1900, CTR-7500, the Magnum Tiltrotor, and the EUROFAR tiltrotor. The tiltwing vehicles include the Canadair CL-84 and the Ishida TW-68. Among the more significant conclusions of this evaluation are the following:

a. Depending on the various factors involved, ALL evaluated configurations do have the potential to create rotorwash related hazards. These hazards will have to be addressed through vertiport design and vertiport operating procedures.

b. The small tiltrotor configurations (XV-15, Magnum Tiltrotor, CTR-800, and CTR-1900) should not create significant rotorwash related problems when operated at most planned vertiports.

c. Operation of the small tiltwing configurations (CL-84 and TW-68) should not create significant rotorwash related problems when operated at most planned vertiports. However, both tiltwing aircraft do generate levels of rotorwash in close proximity to the aircraft that may result in significant amounts of entrained particles being ejected out all azimuths for some types of landing surfaces.

d. Additional research and development is required. (This topic is discussed in section 2.3.6.)

FAA/RD-90/17, Analysis of Rotorwash Effects in Helicopter Mishaps. (NTIS: AD-A243536) For purposes of discussion, let us define two points D and S shown below.

........D......................S......................

Consider the continuum of operations that might take place at a heliport and consider the rotorwash resulting from these operations. Analysis can show that everything to the right of S is safe and that everything to the left of D is dangerous. The definitely dangerous situations can be avoided through heliport

design. The definitely safe situations present no problems. Due to the complexity of the rotorwash issue, however, there is a lot of ground between points D and S where the situation is gray rather than black or white.

Economically, it is not practical to preclude (via heliport/vertiport design or operational restrictions) all operations that fall between points D and S. Currently, it is the pilot's responsibility to avoid rotorwash situations that are dangerous. Anticipating the introduction of larger rotorcraft at public heliports/vertiports, the FAA is trying to gain a better understanding of the rotorwash phenomenon.

By analyzing accidents/mishaps involving rotorwash, the FAA is attempting to determine the thresholds at which rotorwash creates a hazard in a variety of scenarios. In so doing, we hope to reduce the distance between points D and S. We anticipate that the results of this analysis will be of interest to all involved in the operation of larger rotorcraft.

FAA/RD-90/25, Rotorwash Computer Model - User's Guide. (NTIS: AD-A246823) This model is based on measured rotorwash data of various helicopters and of the XV-15 tiltrotor. The efforts documented in the following reports are based on the use of this model:

FAA/RD-90/16, Evaluation of Rotorwash Characteristics for Tiltrotor and Tiltwing Aircraft in Hovering Flight.

FAA/RD-90/17, Analysis of Rotorwash Mishaps.

(This computer model and the associated user's manual have been updated. The new user's guide is FAA/RD-93/31.)

FAA/RD-91/1, Composite Profiles of Helicopter Mishaps at Heliports, Airports, and Unimproved Sites. (NTIS: AD-A248887) This document is a continuation of the effort that produced FAA/RD-90/8 and FAA/RD-90/9. The FAA anticipates that airport/heliport/vertiport designers will take these three documents into consideration in the design process. In so doing, they can avoid by design these potentially hazardous situations. This third document is intended primarily for use by landing site designers and by operators, primarily as a teaching document. However, pilots may also find it of interest as a way to become more aware of the types of accidents and incidents taking place at landing sites and how they can be avoided.

FAA/RD-91/12, New York Downtown Manhattan (Wall Street) Heliport - Operations Analysis. (NTIS: AD-A243207) This report documents a detailed analysis of the numbers and types of operations at the Downtown Manhattan Heliport (Wall Street). It also discusses the history of the facility since its opening in 1960. By documenting operations at successful heliports, the FAA

anticipates that this will provide heliport planners with information that will better enable them to build successful heliports at other locations.

A similar document (FAA/RD-89/32) has been published on the Indianapolis Downtown Heliport.

FAA/RD-92/1, FAA Vertical Flight Research, Engineering, and Development Bibliography, 1962-1991 (NTIS: AD-A248224) This is a bibliography of FAA vertical flight research and development reports published from 1962 to 1991. Abstracts for approximately 300 reports are included along with various indexes to help identify specific documents of interest. This bibliography has been assembled as an aid to those who are interested in research, engineering, and development of vertical flight issues including heliports, vertiports, helicopters, tiltrotor, and tiltwing vehicles. The intended audience includes people within the Federal Aviation Administration (FAA), in industry, and in state and local governments.

FAA/CT-TN92/1, Helicopter Nighttime Parking Test Results - UH-1. (NTIS: AD A253 798) In low level lighting, visual cues deteriorate along with pilot depth perception. Testing was therefore conducted to determine whether larger maneuvering areas are needed at night for operation under low ambient light conditions.

This effort is similar to the daytime testing documented in "Heliport Surface Maneuvering Test Results" (FAA/CT-TN88/30). Over 100 parking maneuvers were conducted by seven subject pilots in a UH-1 under limited lighting/night conditions. These tests were done under various wind conditions (head wind, tail wind, and cross wind) with a lit obstacle, an unlit obstacle, and no obstacle (ground mark for a reference). Regretfully, this was an Army vehicle at the time and virtually all the subjects were high-time helicopter pilots (only one of the seven pilots had less than 1600 hours helicopter time). (For several reasons, these tests should not be considered as worst case. See discussion in section 2.2.5.)

Among the conclusions of this report are the following:

1. During the first portion of the testing, each pilot was asked to state the rotor tip clearance with which he/she would be comfortable. The pilot was then instructed to park parallel to the obstacle with this stated clearance. During this portion of the testing, there were FIVE occasions when the main rotor blades overlapped the test obstacle. (Three of these overlaps occurred when the [illegible]cle was lit. Two overlaps occurred when the obstacle [illegible]nlit.)

2. For safety's sake, the height of the obstacle was a few feet shorter than the main rotor height in a rotor-level configuration. Had the obstacle been a few feet higher during any of the FIVE overlaps experienced during the testing, a serious accident would have resulted.

The five overlaps represent roughly four percent of the total number of operations in the testing. This is a demonstration that the current one third rotor diameter tip clearance is inadequate even with high time helicopter pilots.

Additional analysis of data in FAA/CT-TN88/30 initially suggested that the helicopter requiring the largest tip clearance may be the small, light, skid-equipped helicopter (see Appendix B). Since both the day testing (FAA/CT-TN88/30) and the night testing (FAA/CT-TN92/1) were done with a large, heavy UH-1H helicopter, this analysis suggested that the results might not represent the most demanding case. The results of FAA/CT-TN88/30 also indicated that pilots desire more tip clearance when the obstacle is another aircraft. In this test, the obstacle was a truck. Thus, the results are likely to be less demanding than if the obstacle had been another helicopter.

The testing provides a measure of pilot performance errors (the difference between actual tip clearance and the intended tip clearance) and pilot perception errors (the difference between the actual tip clearance and the pilots estimate of tip clearance). As might be expected, judging tip clearances was considerably more difficult at night than during the day. When nighttime operations are conducted in limited ambient lighting, roughly 25 percent additional tip clearance is required to provide a comparable level of safety.

RD-92-1-LR, Rotorwash Wind Effects Flight Test Plan. (Not available from NTIS) This test is designed to obtain data for use in analyzing the effects of ambient winds on the rotorwash flow fields of single-main-rotor helicopters. It is generally understood that ambient winds can significantly affect rotorwash flow field characteristics. In some cases, this may lessen the potential rotorwash hazards. In other cases, it may increase the potential hazards. Additional data are needed to better understand the details of this effect.

RD-92-2-LR, Acceptable Rotorwash Personnel Thresholds Flight Test Plan. (Not available from NTIS) This test describes flight tests needed to define acceptable limits of overturning force and moment values for civilian ramp personnel and passengers. At a vertiport, there may be two or more gates for passenger entry and

exit. Maximum operational flexibility and capacity would require the ability to operate independently at each gate. This would involve the ability to load or unload passengers at one gate while the aircraft at the next gate is taxiing in or out of the gate. Testing and analysis are required to determine the separation required between adjacent gates where independent operations are desirable.

(One alternative solution would be to accept the operational constraints involved with dependent operations at adjacent gates in order to decrease the area required for a vertiport. Another alternative solution would involve the installation of enclosed walkways/jetways similar to those used now at major airports. Once all of these solutions are defined and understood, the rotorcraft community will be in a position to choose the best solution for each given facility.)

RD-92-3-LR, S-76 Rotorwash Flight Test Plan. (Not available from NTIS) This test plan was designed to facilitate a comparison of different types of rotorwash measurement/instrument techniques. The first technique was used by the Naval Air Warfare Center (NAWC), Aircraft Division. This technique used ion-beam deflection wind velocity sensors. The second technique was used by the FAA Technical Center and used electro-mechanical wind velocity sensors.

[Subsequent to the development of this test plan, the FAA accomplished the purposes of this test via an alternate test. (The results of this test are documented in FAA/RD-93/10, Rotorwash Wind Sensor Evaluation. See section 2.3.1 for a discussion of the results.)]

RD-92-4-LR, XV-15 Rotorwash Flight Test Plan. (Not available from NTIS) This test plan is designed to facilitate a comparison of two different types of rotorwash measurement/instrument techniques. The first technique was used by the Naval Air Warfare Center, Aircraft Division. This technique used ion-beam deflection wind velocity sensors. The second technique was used by the FAA Technical Center and used electro-mechanical wind velocity sensors.

[Subsequent to the development of this test plan, the FAA accomplished the purposes of this test via an alternate test. (The results of this test are documented in FAA/RD-93/10, Rotorwash Wind Sensor Evaluation. See section 2.3.1 for a discussion of the results.)]

FAA/RD-92/15, Potential Hazards of Magnetic Resonance Imagers to Emergency Medical Service Helicopter Operations. (NTIS: TBD) At hospital heliports, the FAA has received reports that some magnetic resonance imagers (MRI) have caused interference to the magnetic compasses and associated avionics on helicopters.

The MRI uses an intense magnetic field and radio frequency energy to produce detailed images of human soft tissue. The medical value of these machines is unquestioned. However, in recent years there have been numerous incidents where MRI's have interfered with the operation of magnetic compasses and directional gyroscopes on helicopters and caused these magnetic instruments to give false readings with large azimuthal errors. These effects have appeared to be temporary and, to date, no mishaps or accidents have been attributed to such interference. However, there is a concern that an accident might result from these temporary effects.

The FAA investigated the potential hazards of MRI's to helicopter avionics. The following is a concise statement of our findings:

a. The main hazard from MRI fringe fields is that they can cause magnetic sensors to give aberrant readings. These fields are strong enough to influence magnetic sensors (compasses and flux gates) on a helicopter out to a distance of 500 feet from the center of the MRI magnet. As long as the pilot is aware of the possibility of anomalous readings, this should not constitute a hazard for VFR flights. However, under IFR flight, anomalous readings could lead a pilot into unprotected airspace and collision with an obstacle. For this reason, the allowable strength of MRI fringe fields must be limited to 0.005 Gauss if IFR operations are to be conducted at the hospital heliport.

b. Fringe fields from an MRI are strong enough to influence cathode ray tubes and night vision goggles. Although no occurrences of distortion on such helicopter avionics have been documented, EMS operators and the FAA should consider this effect when considering operations near MRI's.

c. Maintaining adequate separation from MRI magnets is the most effective means of avoiding adverse effects of MRI's on helicopter systems. To preclude such effects at an IFR heliport, the FATO and the edges of the approach/departure surface(s) should be geographically separated from the MRI. A separation of 500 feet will preclude interference from a powerful, unshielded MRI. For less powerful and/or shielded MRI's, the heliport FATO or the edges of the approach/ departure surface(s) should not be within the 0.005 Gauss line of the MRI.

d. Vigilance of flight crews, helicopter operators, and hospital administrators is required to minimize potential hazards from MRI fringe fields. Cooperation among all three groups is necessary to ensure that a helicopter is never inadvertently exposed to a fringe field.

e. Most MRI's operate continually because of the high cost of shutting them down. Pilots should never assume that an MRI has been shut off. Rather, they should assume that the magnetic fringe field is always present and that the fringe field will affect magnetic sensors.

f. Heliport owners and users should take steps to make pilots aware of the locations of MRI's and their potential safety hazards. In addition, signs should be posted in the vicinity of the heliport to alert pilots of the nearby presence of an MRI.

MRI magnetic interference is discussed in FAA/RD-92/15, Potential Hazards of Magnetic Resonance Imagers to Emergency Medical Service Helicopter Operations. This document focused on VFR heliports. At IFR heliports, azimuthal errors of magnetic compasses and directional gyroscopes are considerably more serious. With the advent of GPS, a significant number of heliports, particularly hospital heliports, are likely to seek instrument approach procedures. The FAA is considering whether additional study is required on the potential impact an MRI could have on instrument operations at IFR heliports.

There are other very strong magnetic devices being developed, some that are considerably more powerful than the typical MRI. One such device, a superconducting magnetic energy storage unit (SMES), is being developed by the Army Corps of Engineers and the Department of Energy. While the FAA MRI research effort did not specifically address the SMES, it is likely that the results will be helpful in considering the environmental impact of the SMES and other very powerful magnetic devices.

Both MRI's and SMES are high power magnets that can cause magnetic interference out to considerable distances. Industry has reported azimuthal errors of 60 degrees from low power magnetic devices such as elevator motors. Unlike MRI's, only a modest investment is required to mitigate such interference by shielding the elevator motors. In FAA/RD-92/15, simple procedures for determining the presence of magnetic interference at a heliport site will work equally well regardless of whether the source of the interference is an MRI, an elevator motor, or some other source.

FAA/RD-92/46, VMC Left Turn Curved Approaches - Test Results. (NTIS AD A269 476) This effort documents flight testing of left turn curved approaches to a heliport under VMC conditions. (Left turns, in comparison with right turns, are considered a worst case scenario. A limited program of right turn approaches is under consideration.) Approaches were flown with minimum straight segments of 800, 1200, and 1600 feet. Testing included procedures with intercept angles of 45, 90, and 180 degrees. (By intercept angle, we mean the angle between the initial approach

azimuth and the azimuth of the extended centerline of the minimum straight segment prior to touchdown.)

Using a Sikorsky S-76, 19 subject pilots completed a total of 610 approaches. Using a Bell UH-1H, 16 subject pilots completed a total of 522 approaches. Subject pilots provided in-flight ratings of the various approaches. With regard to workload, safety, and controllability; the FAA requested pilot ratings within the following structure:

Group 1: acceptable procedure for routine operation
Group 2: acceptable only on occasion
Group 3: inadequate safety margin and major deficiencies

Of 3396 total ratings, 3121 (91.9 percent) were in Group 1, 266 (7.8 percent) were in Group 2, and 9 (0.26 percent) were in Group 3. (Of the Group 3 ratings, 2 were from UH-1H pilots and 7 were from S-76 pilots. Of the Group 2 ratings, 70 were from UH-1H pilots and 196 were from S-76 pilots.)

Looking at the composite profiles of lateral dispersion, it is clear that the lateral dispersion during the curve is broader than the lateral dispersion at the same distance from the helipad for a straight approach. This is even true at both end of the final straight segment of the approach.

Looking at the issue of minimum straight segments for curved approaches, test results indicate that a significant number of pilots are uncomfortable with a straight segment that is less than 1200 feet in length.

While curved approaches and departures require more airspace, they do offer greater flexibility in siting heliports. Thus, it would be appropriate to quantify these airspace requirements in order to allow industry to take advantage of this flexibility. Federal Aviation Regulations (FAR) Part 77 should be modified to address the larger airspace required for VFR heliport curved approaches and departures. Once this has been accomplished, changes would also be appropriate in the Heliport Design advisory circular (AC) and in the Vertiport Design AC.

FAA/RD-93/2, Rooftop Emergency Heliports. (NTIS: TBD) This effort includes an in-depth analysis of high-rise building fires in which helicopters were used for fire-fighting/rescue missions, a study of building codes that are applicable to the design and construction of rooftop heliports, and a review of the 1988 Heliport Design AC as it applies to such facilities.

Helicopters have made significant contributions to the successful outcome of high-rise building fires. Helicopters missions have included moving fire department personnel and equipment to and from the roof, survey of the progress of the fire, directing

rescue personnel to occupants who were near windows, and evacuation of occupants from the roof.

All three of the major US building codes lack a specific approach to rooftop heliport design. However, the heliport loading requirements for the Uniform Building Code and the Southern Building Code are adequate. Heliport loading requirements for the National Building Code are generally adequate but are not specific with regard to uniform live load for heliports.

There is a broad divergence of opinion among fire-fighting professionals on the need for and use of rooftop emergency heliports. In certain areas, California in particular, rooftop emergency heliports are required by law for all new high-rise buildings. In other parts of the country, rooftop emergency heliports are not encouraged. This report will provide useful information to anyone with an interest in such facilities.

FAA/CT-TN93/6, Combined 1991 and 1992 Robinson - 22B (R-22) Parking Test Results. (NTIS: TBD) Analysis of subjective pilot opinions (see appendix B) had initially suggested that the helicopter requiring the largest tip clearance during ground maneuvers might be the small, light, skid-equipped helicopter. This report documents the daytime testing of a Robinson R-22 (with a 25.2 foot rotor diameter). The tests are similar to those documented in FAA/CT-TN88/30 and FAA/CT-TN92/1. When the subject pilots were asked to park with an unspecified "safe" rotor tip clearance from another aircraft or from a ground marking, actual tip clearances varied from 1.51 to 23.64 feet with an average of 11.0 feet. When the subject pilots were asked to park with a rotor tip clearance of 10 feet, actual tip clearances varied from 2.88 to 25.94 feet with an average of 14.5 feet.

FAA/CT-TN93/6 also shows that a 10 foot tip clearance requirement is inadequate for an R-22. Rather, the results point to a minimum requirement of about 20 - 25 feet. This is just slightly larger than the 20 foot tip clearance desired by the 50 percentile pilot in rotorcraft with rotor diameters of 30 feet or larger (see Appendix B, figure 4). However, it is considerably smaller than the 40 foot tip clearance desired by the median (50 percentile) pilot in rotorcraft with rotor diameters of 25 feet.

FAA/RD-93/10, Rotorwash Wind Sensor Evaluation.
(NTIS: AD-A269188) The FAA has collected rotorwash data in an effort to better understand the rotorwash phenomenon and the operational environment at vertical flight landing sites. Results are published in the following reports:

FAA/CT-TN87/54, Analysis of Heliport Environmental Data: Indianapolis Heliport, Wall Street Heliport

Vol. 1, Summary
Vol. 2, Wall Street Heliport Data Plots
Vol. 3, Indianapolis Downtown Heliport Data Plots

FAA/CT-TN89/43 Analysis of Heliport Environmental Data: Intracoastal City, LA.

These data were collected using a electro-mechanical sensor, specifically, a Belford Instrument Company S-122 HD Wind Vector Transmitter. These transmitters consist of two major elements: an upper section containing a wind speed generator attached to an airplane rudder shaped vane, and a fixed, vertical support and connector housing. The wind speed generator is driven by a six-blade propeller.

Due to the inertia characteristics of this device, questions were raised as to whether this type of electro-mechanical sensor under-reports the peak pulses of the rotorwash. In the late 1980's, in anticipation of additional rotorwash testing, the FAA Technical Center replaced their Belford wind sensors with Qualimetrics Model 2132 wind speed and direction sensors. (The Belford wind sensors were sold as surplus government equipment.) Although the original wind sensors were no longer available, the FAA still wanted to gain a better understanding of the characteristics and limitations of electro-mechanical sensors.

Rotorwash data have also been collected by the Navy's Systems Engineering Test Directorate at the Patuxent River Naval Air Station using a two axis ion beam deflection anemometer. This device is considered to be perhaps the best available instrument for measuring rotorwash velocity. This report compares the performance of the two types of wind sensors. Test conditions included both wind tunnel testing and side-by-side testing in close proximity to a hovering helicopter.

Test results show that the Qualimetrics Model 2132 Wind Sensor does not accurately measure a rotorwash flow field in terms of frequency amplitude, frequency content and velocity magnitude. Thus, it is not recommended for helicopter rotorwash velocity data collection. Although the Belford Instrument Company S-122 HD Wind Vector Transmitter was not specifically tested, as a electro-mechanical sensor, it is reasonable to expect that it has the same physical limitations as the Qualimetrics sensor.

What are the implications of this wind sensor comparison with regard to the data contained in reports FAA/CT-TN87/54 and FAA/CT-TN89/43?

- The rotorwash data in these documents allow a reasonable comparison between the relative magnitude of the rotorwash characteristics of different helicopters.

- However, the data in these documents significantly underestimate the severity of the rotorwash phenomenon. With the peak wind velocity, for instance, a limited sample shows that the Qualimetrics Model 2132 sensor under-reported the peak velocity by as much as 19 knots in comparison with an ion beam deflection wind sensor.

FAA/RD-93/22, Rotorcraft Low Altitude IFR Benefit/Cost Analysis: Methodology and Application. (NTIS: AD-A274241) This is the third of a three volume set of documents. This final report reviews the operational requirements and constraints for specific rotorcraft missions identified in the previous reports in this series. It also reviews all of the alternatives identified for improving rotorcraft operations. The alternatives considered include nonprecision approaches to heliports, additional communications and surveillance equipment, and air traffic control procedural changes. A benefit/cost analysis is conducted for each nonprecision approach, communication, surveillance, and procedural improvement identified. Heliport/vertiport planners may find the information on nonprecision approaches of particular interest. In view of the benefits of nonprecision approaches, planners would be well advised to ensure that the majority of all new landing facilities have the ground area and airspace to support nonprecision operations even if they don't expect to provide such services immediately.

4.0 **VERTICAL FLIGHT LANDING SITE DESIGN AND PLANNING - REPORTS IN PROGRESS.** In addition to what has been published, there are a number of efforts in process on design and planning issues. These are listed below in chronological order. Once published, these reports will be available from the sources listed in section 1.3.

FAA/CT-TN93/24, Visual Meteorological Conditions (VMC) Right Turn Curved Approaches. (NTIS: TBD) The right turn flight testing is similar to the earlier left turn testing documented in FAA/RD-92/46, VMC Left Turn Curved Approaches - Test Results. Right turn test results are very comparable and they confirm the earlier assumption that the left turn approaches will generally require more airspace than the right turn approaches.

FAA/RD-93/31, Rotorwash Analysis Handbook. (NTIS: TBD) Both during and subsequent to the work documented in FAA/RD-90/16, FAA/RD-90/17, and FAA/RD-90/25; additional rotorwash work was conducted by other researchers. In response to this work and to encouragement from industry, the FAA decided to update the computer model and several of the associated reports (FAA/RD-90/25 and FAA/RD-90/17). The Rotorwash Analysis Handbook replaces both of these documents with a report that provides numerous "How To" examples. As civil rotorcraft continue to increase in size and weight, this computer model will serve as an important tool to help designers avoid rotorwash induced accidents.

FAA/RD-93/37, Analysis of Vertiport Studies Funded by the Airport Improvement Program (AIP). (NTIS: TBD) In 1988, the FAA funded 13 studies in a program of vertiport feasibility studies. Transport Canada funded a study of their own. This report evaluates these 14 studies and provides an overview of the results.

FAA/RD-94/xx/LR, VFR Heliport Obstacle-Rich Environments: Test and Evaluation (Not available from NTIS)

FAA/RD-94/xx/LR, VFR Heliport Obstacle-Rich Environments: Simulation Requirements and Facilities (Not available from NTIS)

FAA/RD-94/xx/LR, VFR Heliport Obstacle-Rich Environment: Draft Test Plan (Not available from NTIS)

FAA/RD-94/xx/LR, VFR Heliport Obstacle-Rich Environments: Pilot Briefing Material (Not available from NTIS)

At many existing heliports, the available airspace exceeds the current minimum requirements. However, as more heliports are located in city-center areas, and as the number of obstacles continues to grow in these cities, the issue of a very large number of obstacles will become a growing concern. The New Orleans Downtown Heliport is a case in point. Pilot reaction to

the New Orleans Downtown Heliport raised an FAA concern that a large number of obstacles might make a given heliport unacceptable to user pilots even if none of these obstacles is an obstruction as defined by FAR 77, Objects Affecting Navigable Airspace.

To examine this issue, the FAA has started to develop plans for simulation testing of VFR helicopter operations in obstacle-rich environments. Using these data, the FAA will then determine the effect of these obstacles on pilot performance. In this way, it may be possible to develop a means of defining requirements in obstacle-rich environments. At this time, it is uncertain whether this will involve additional lateral and/or vertical airspace, additional clear space on the ground, specific emergency landing sites, etc. The most effective means for collecting these data is to use a well-instrumented, piloted helicopter visual simulator. These four reports will document various facets of the FAA plans and requirements for this effort.

5.0 <u>VERTICAL FLIGHT LANDING SITE PLANNING REPORTS</u>. This section contains a synopsis of recent FAA R&D efforts involving heliport/vertiport planning and system planning issues.

FAA/PM-87/31, Analysis of Heliport System Plans.
(NTIS: AD-A195283) This study analyzed the strengths and weaknesses of four state and four metropolitan heliport system plans. Planning concepts are identified and defined to include:

a. baseline parameters for evaluating the plans,

b. identifying the data (and their sources) needed for planning purposes at any jurisdictional level, and

c. developing criteria for assessing the feasibility and economic viability of proposed heliport facilities.

(The four state plans reviewed were Michigan, New Jersey, Louisiana, and Ohio. The four metropolitan plans reviewed were Pittsburgh, Phoenix, Houston, and Washington, DC.)

FAA/PM-87/32, Four Urban Heliport Case Studies.
(NTIS: AD-A195284) This study developed case histories of four heliports built in the central business districts of major cities. [The heliports studied were the Bank-Whitmore Heliport (Nashua Street Heliport) in Boston, the Indianapolis Downtown Heliport, the New Orleans Downtown Heliport, and the Western and Southern Heliport in Cincinnati.] The effort identified six essential elements of a successful heliport. Consideration of these elements would aid in the prediction of whether a proposed heliport will succeed or fail. These six elements are

- o location
- o demand
- o local government attitude
- o public attitude
- o financial backing
- o integral planning

FAA/PM-87/33, Heliport System Planning Guidelines.
(NTIS: AD-A199081) This report provides recommendations on the necessary content of a state or metropolitan heliport system plan. A subset of this information was formatted into a draft heliport system planning chapter in the FAA advisory circular on state airport system planning. However, since this chapter seven is as large or larger than the remaining six chapters of this AC, the FAA is considering making it a stand-alone advisory circular.

FAA/EE-88-2, Heliport Noise Model (HNM) Version 1 User's Manual.
(NTIS: AD-A219555) The Heliport Noise Model is a computer tool for determining the total impact of helicopter noise at and around heliports. The model runs on IBM PC/XT/AT personal computers and other compatible computers. This manual contains a general description of elements of a heliport noise case study and specific instructions for preparing the case for input.

Currently, this model is being revised. Improvements are being made to the user interface. In addition, changes are being made to the method for calculating helicopter noise during taxi operations. No release date for the revised model has been announced.

FAA/DS-89/9, Rotorcraft Low Altitude CNS Benefit/Cost Analysis, Rotorcraft Operations Data. (NTIS: AD-A214113) This is the first of a three volume set of documents. The objective of this study is to determine if there is an economic basis for improvement of low altitude instrument flight rules (IFR) services within the National Airspace System (NAS) in order to better support rotorcraft IFR operations. This first report provides background data on the rotorcraft industry as well as forecasts to the year 2007 for the purpose of providing operational data for analyses of long-term benefits and costs. It describes rotorcraft missions, selects those most likely to benefit from increased availability of IFR services, identifies the probability of various ceiling and visibility combinations within selected rotorcraft operating areas, and presents an inventory of rotorcraft activity by mission and location. While this first report does not deal specifically with heliports/vertiports, it contains a wealth of data that heliport/vertiport planners may find of interest.

FAA/DS-89/10, Rotorcraft Low Altitude IFR Benefit/Cost Analysis: Operational Analysis. (NTIS: AD-A246865) This is the second of a three volume set of documents. This second report defines operational requirements and constraints for selected rotorcraft missions. A candidate list of 50 sites around the country, selected for their potential to benefit from increased low altitude IFR services, is presented. Radar and communications coverage in those areas are then identified. CNS improvements to be provided by implementation of the NAS plan, relevant FAA policies, ATC procedures, and avionics improvements are analyzed for their potential to benefit low altitude rotorcraft IFR operations. Finally, a benefit/cost methodology to determine where the most benefits would accrue from improvements in rotorcraft low altitude IFR services or changes in ATC procedures is presented.

FAA/DS-89/11, Rotorcraft Low Altitude IFR Benefit/Cost Analysis: Methodology and Application. (NTIS: AD-A274241) This is the third of a three volume set of documents. This final report reviews the operational requirements and constraints for specific rotorcraft missions identified in the previous reports in this series. It also reviews all of the alternatives identified for improving rotorcraft operations. The alternatives considered include nonprecision approaches to heliports, additional communications and surveillance equipment, and air traffic control procedural changes. A benefit/cost analysis is conducted for each nonprecision approach, communication, surveillance, and procedural improvement identified. Heliport/vertiport planners

may find the information on nonprecision approaches of particular interest. In view of the benefits of nonprecision approaches, planners would be well advised to ensure that the majority of all new landing facilities have the ground area and airspace to support nonprecision operations even if they don't expect to provide such services immediately.

FAA/DS-89/32, Indianapolis Downtown Heliport - Operations Analysis and Marketing History. (NTIS: AD-A222121) This report documents a detailed analysis of the numbers and types of operations at the Indianapolis Downtown Heliport from its opening in 1985 through March 1989. It also discusses the marketing techniques used during the planning and development stages of the heliport as well as the continuing marketing effort used to retain and increase business. By documenting operations at successful heliports, the FAA anticipates that this will provide heliport planners with information that will better enable them to build successful heliports at other locations.

A similar document (FAA/RD-91/12) has been published on the Downtown Manhattan Heliport (Wall Street).

FAA/RD-90/10, Rotorcraft Use in Disaster Relief and Mass Casualty Incidents - Case Studies. (NTIS: AD-A229401) This report documents rotorcraft involvement in disaster relief efforts and provides a general understanding of the nature of the rotorcraft portion of such operations. A representative series of 18 case studies detailing disaster situations (i.e., natural disasters, high rise fires, airline crashes, etc.) where rotorcraft have been involved in relief and rescue operations are analyzed. Each case addresses the circumstances of the disaster, the extent of rescue and relief efforts, the nature and extent of prior relief planning, the nature of the actual rotorcraft involvement, the number of people assisted via helicopter transportation, the types of landing areas used, the lessons learned, and the post-situation analysis. In these 18 cases, rotorcraft transported approximately 3,357 people and helped to save at least 187 lives.

By addressing cases where rotorcraft have provided life saving services to the local community, this report provides a dramatic answer to the question: "Why should we let you build a heliport in our neighborhood?"

FAA/RD-90/11, Guidelines For Integrating Helicopter Assets into Emergency Planning. (NTIS: ADA-241479) In the last four decades, rotorcraft have proven their capability to provide unique assistance in disaster relief operations. Yet both the public and emergency preparedness and disaster relief officials are generally unaware the details of rotorcraft capabilities and the extensive planning required to enable rotorcraft to assist most effectively. Consequently, they do not take best advantage of the assets (civil and military rotorcraft and the local

landing sites) that are available to help deal with a crisis situation.

These guidelines advise how to best integrate rotorcraft into existing disaster relief planning. Advice is given on the inventory of rotorcraft, heliports, participant surveys, rotorcraft dispatch center functions, communications requirements, designation and establishment of landing zones, and plan implementation. This report builds on the case studies contained in report FAA/RD-90/10. Both documents convey that rotorcraft and heliports are valuable community assets, readily available to assist in life saving efforts when needed.

FAA/RD-91/7, Air Ambulance Helicopter Operational Analysis. (NTIS: ADA-237666) This study discusses flight rules (VFR) weather minimums and describes the local and cross country operational areas for helicopter emergency medical service operations across the country. The national average of VFR operational weather minimums for all respondents was determined. Also, an estimate of the percentage of time that each respondent can not fly because of ceiling and/or visibility below their VFR operating minimums was determined, as was the average percentage of time all responders can not fly.

The coverage areas reported by the operators were plotted on two maps of the United States, one for the local coverage areas and one for the cross country coverage areas. From these maps, the percentage of coverage for the conterminous United States, each FAA region, and each state were determined. The weather data were also averaged over each state and used to determine the percentage of time that coverage is available in areas where EMS/H service is provided.

A recent FAA study (FAA/DS-89/11) found that the helicopter ambulance mission is a source of significant social benefits to the nation in terms of lives saved and reduced medical recovery times. The results of the Air Ambulance Helicopter Operational Analysis provided data which supported analysis of the benefits of rotorcraft in an IFR environment.

FAA/DS-91/12, New York Downtown Manhattan Heliport - Operations Analysis and Marketing History. (NTIS: AD-A243207) This document provides a general overview of the Wall Street Heliport since its inception in 1960 and a detailed analysis of the numbers and types of operations between 1987 and 1989. In addition, the developmental history of the facility is discussed. By documenting operations at successful heliports, the FAA anticipates that this will provide heliport planners with information that will better enable them to build successful heliports at other locations.

A similar document (FAA/RD-89/32) has been published on the Indianapolis Downtown Heliport.

FAA/RD-93/22, Rotorcraft Low Altitude IFR Benefit/Cost Analysis: Methodology and Application. (NTIS: AD-A274241) This is the third of a three volume set of documents. This final report reviews the operational requirements and constraints for specific rotorcraft missions identified in the previous reports in this series. It also reviews all of the alternatives identified for improving rotorcraft operations. The alternatives considered include nonprecision approaches to heliports, additional communications and surveillance equipment, and air traffic control procedural changes. A benefit/cost analysis is conducted for each nonprecision approach, communication, surveillance, and procedural improvement identified. Heliport/vertiport planners may find the information on nonprecision approaches of particular interest. In view of the benefits of nonprecision approaches, planners would be well advised to ensure that the majority of all new landing facilities have the ground area and airspace to support nonprecision operations even if they don't expect to provide such services immediately.

FAA/RD-93/37, Analysis of Vertiport Studies Funded by the Airport Improvement Program (AIP). (NTIS: TBD) In 1988, the FAA funded 13 studies in a program of vertiport feasibility studies. Transport Canada funded a study of their own. This report evaluates these 14 studies and provides an overview of the results.

6.0 SAFETY PERSPECTIVE

How safe is "safe?" For what should the vertical flight industry be striving? Before answering this question, let us consider the remarks of Congressman Mineta in a 1984 speech to the American Institute of Aeronautics and Astronautics (see appendix A for the full text). The Congressman addressed these specific questions giving his viewpoint on the industry as a whole and the air transport segment in particular. One could condense his remarks to the following concise statement:

> Everybody is in favor of safe transportation but what does that mean? What level of risk is acceptable? Looking at our society, the answer varies widely by mode of transportation. In the past five years, there has been an average of 150 fatalities per year in air carrier accidents and nearly 50,000 highways deaths per year. Comparing the two modes of transportation, air carrier transportation is dramatically safer than travelling by automobile.
>
> But most Americans do not recognize this. They jump into the family car with little or no safety concern, but their anxiety levels go up when they board an airplane. This is what determines, in our society, how safe is "safe" for each mode of transportation.
>
> I would suggest that 150 air carrier fatalities per year and 50,000 highway fatalities per year is an indication of what our society considers an acceptable level of safety for each of these modes. Not acceptable in terms of desirable, not acceptable in the sense that people don't mind these fatalities, but acceptable in the sense that, at these levels, most Americans are willing to use these modes of transportation and accept the associated risk.
>
> The risk of highway accidents could be easily reduced if we really wanted to do so. It has been estimated that 15,000 lives could be saved annually if everyone would use seat belts. Only about 14 percent do. Roughly 90 percent of all child passenger fatalities could be prevented with seat belts. Yet we use them only about 40 percent of the time. Thus, as a society, we ACCEPT 50,000 highway deaths in that remedies are readily available and we choose not to apply them.
>
> Our society clearly imposes a much higher safety standard on aviation than it does on highways. In fact, the discrepancy between the two standards is clearly beyond reason. In spite of this, if aviation is to thrive and grow in our society, it has to meet our society's safety standards, whatever those standards might be.

> In a mode of transportation that already has a superlative safety record, additional safety improvements are difficult but not impossible. Aviation accidents have not come to an irreducible plateau. There are steps that can be taken to improve safety. How safe is safe? For aviation, our society basically has a two-part answer:
>
> (1) Safer than for other modes of transportation, and by a wide margin, and
>
> (2) Safer with each passing year.
>
> Aviation has grown in part because it has shown an ever improving safety record. As outstanding as this safety record is, our society expects that it will continue to improve. Aviation got where it is today by meeting safety standards that are far more demanding than most other modes of transportation have to meet. Aviation must continue to meet those ever higher standards.

While the Congressman's remarks are not specifically addressed toward the vertical flight segment of the industry, these remarks could easily be paraphrased as follows:

> In a vertical flight mode of transportation that has made significant improvements over the last several decades, additional safety improvements are more difficult to obtain. However, they are not impossible. Vertical flight accident rates have not come to some irreducible plateau. There are steps that can be taken to further improve safety performance in the vertical flight industry.
>
> How safe is safe? For the US vertical flight industry, our society has a two part answer:
>
> (1) As safe or safer than comparable segments of aviation conducting similar missions, and
>
> (2) Safer with each passing year.
>
> The vertical flight industry has long been focused on special assignment missions, missions that no other aircraft could accomplish. In recent years, however, various advocates have raised the possibility that vertical flight aircraft will eventually carry a significant percentage of the total yearly number of aircraft passengers. In certain markets, tiltrotor aircraft and larger helicopters hold significant promise as passenger carrying vehicles in the near future. If these aircraft are to fulfill this promise, however, the industry must recognize that this mission entails responsibilities beyond those associated with more traditional helicopter missions.

The vertical flight industry has grown in part because it has shown an ever improving safety record. Our society expects that this safety record will continue to improve. If this happens, the industry will continue to grow, expanding into the missions of scheduled commuter and air transport operations. If this does not happen, society will look for other ways to satisfy its transportation needs.

7.0 CONCLUSIONS

Vertical flight landing site design standards ought to represent a balance between safety and cost. Over the years, the vertical flight industry has argued strongly for the FAA to lessen the economic impact of heliport design standards. Consequently, the FAA Heliport Design AC is structured as a "minimum requirements" document. There are good reasons to develop such a design document using this approach. However, recent test results show that some of these "minimum requirements" are inadequate. In addition, one should realize that for private heliports, many heliport design parameters have NO minimum requirements in the 1994 Heliport Design AC. For some design parameters, test results raise the issue of whether the current standards represent the proper balance between safety and cost.

7.1 Conclusions - Minimum Heliport VFR Airspace. The FAA has studied this issue in a multi-faceted R&D program involving flight testing, analysis of certification data, operational survey of industry helicopter pilots, and helicopter accident analysis. To varying degrees, each facet of this effort indicates a need for an increase in the minimum required VFR heliport airspace.

In the short term, heliport design standards need to be revised to require an acceleration area prior to the start of the approach/departure surface. (The required acceleration distance depends on heliport altitude.) The width of the approach and departure paths needs to be increased from 500 feet to 1040 feet (see figure 3). Obstacles near the heliport and the approach and departure paths should be marked and lighted even if the landing site is only used under VFR conditions (see figure 4).

In the longer term, greater flexibility is possible in developing VFR heliports with steeper than an 8 to 1 primary surface. However, there are changes that would have to be made in the infrastructure to support safe operations under this scenario (see document FAA/RD-90/4).

7.2 Conclusions - Parking and Maneuvering Areas. Based largely on the testing documented in FAA/CT-TN88/30, the FAA adopted a tip clearance of one half the rotor span of a tiltrotor aircraft in the Vertiport Design Advisory Circular AC150/5390-3. During the revision of the Heliport Design AC, the FAA reexamined whether one half rotor diameter was an appropriate safety margin for heliport design. Closer examination of the data in FAA/CT-TN88/30 provides some interesting insights on this question. (This topic is discussed in detail in Appendix B.) Nighttime UH-1H testing and daytime R-22 testing have also provided additional insight on this issue.

The analysis contained in Appendix B of this document raised the question of whether conventional design wisdom is fundamentally

flawed with regard to tip clearances. Initially, pilot surveys suggested that the minimum tip clearance required was indirectly rather than directly proportional to the rotor diameter. However, subsequent testing (FAA/CT-TN93/6) suggests that tip clearance requirements are relatively constant as a function of rotor diameter (see Appendix B).

A one third rotor diameter tip clearance is inadequate for large helicopters, even during daylight hours, and particularly inadequate for very small helicopters. Tip clearance is particularly a concern at heliports where night operations are conducted at night under low-ambient-light conditions. Accurately judging tip clearances is difficult during the day. At night, however, this task is even more difficult since pilot depth perception deteriorates significantly. When nighttime operations are conducted in limited ambient lighting, testing indicates that roughly 25 percent additional tip clearance is required to provide a comparable level of safety.

In summary, flight testing, subjective pilot surveys, and accident analysis have all supported the requirement for additional parking and maneuvering space.

7.3 Conclusions - Rotorwash. With the introduction of large tiltrotor (and larger helicopters) at public facilities, the risk of rotorwash induced accidents increases. It would be safer not to depend too heavily on pilot judgment to avoid all potential hazardous situations involving rotorwash. Some potential hazards can best be avoided by developing standard operating procedures and by implementing operational constraints. Others will be best addressed by precluding the hazard via facility design. Rotorwash is an extremely complex phenomenon.

Additional work is required before informed choices can be made as to how potential rotorwash hazards can best be addressed. At this point, it is premature to speculate in detail concerning how the details of the rotorwash issue will be resolved. However, the rotorwash analysis computer model (FAA/RD-93/31) will serve as a valuable tool to help heliport/vertiport/airport designers avoid rotorwash induced accidents.

7.4 Conclusions - Helicopter Accident Analysis. One objective way to determine if things are going well is to look at accident rates and the data on individual accidents. Helicopter accident rates have improved dramatically over the last several decades. These rates have improved to the point where continued improvements are increasingly difficult and expensive to achieve.

And yet, improvement must continue because the public demands that all facets of the aviation industry must show yearly improvements in their accident rates (see additional discussion on this issue in section 6.0, Safety Perspective).

Perhaps the strongest argument in favor of the need for continued safety improvements is seen in the industry's need for additional landing sites. When a heliport is proposed, community objections often focus on the issue of safety and the concern that there is a risk associated with having a heliport as a neighbor. Analysis of accident data shows that heliports are safe neighbors. While people often voice concerns about the possibility of a helicopter accident causing them personal injury or property damage, such an event is extremely rare. Continued improvement in accident rates will help to mitigate public concerns.

At the same time, however, analysis has shown that, during the 1977 - 1986 time period, roughly 34-39 percent of all helicopter accidents occurred at or within one mile of landing sites. Of the total number of helicopter accidents, the approximate percentages that occurred at different types of landing sites are as follows: 13-18 percent at or near airports, 3-5 percent at or near heliports, and 9-18 percent at or near unimproved landing sites. With approximately 3-8 percent of all helicopter accidents, National Transportation Safety Board records do not specify the nature of the landing site.

Some improvement in the accident rates can be accomplished with better training and better operational constraints at heliports. Some can be accomplished via changes in the heliport design criteria. At this point, however, perhaps the greatest safety improvements can be obtained by striving to bring a larger number of heliports into full compliance with the standards and recommendations of the current Heliport Design AC. All of these improvements are likely to be required if the vertical flight accident rate is to continue to improve.

The vertical flight industry has grown in part because it has shown an ever improving safety record. Our society expects this safety record to continue to improve. If this happens, opposition to heliports can be expected to lessen and the industry can continue to grow, expanding into the missions of scheduled commuter and air transport operations. If this does not happen, people will continue to oppose new heliports and society will look for other ways to satisfy their transportation needs.

7.5 Conclusions - Heliport/Vertiport Marking Symbols. As a safety aid, the heliport and vertiport marking symbols can be more useful than what is generally recognized. A properly chosen symbol can satisfy an impressive list of requirements (see section 2.5.1), each of which constitutes a type of assistance to the pilot during the approach. Such assistance provides for a safer approach. Consequently, standard marking symbols should be used at both public and private heliports and vertiports. Few safety aids are more cost effective than the use of this little bit of reflective paint.

The use of personal initials or a company logo may provide some ego satisfaction but this is accomplished at the price of a decrease in heliport safety. Such non-standard symbols should be discouraged. Round logo's are among the worst possible symbols to use as a heliport marking.

Heliport designers and operators would do well to review the conclusions of section 2.5.1 and adjust the size and type of symbol that marks their heliport accordingly.

Several states have developed requirements for heliport markings. As an example, one state requires all private heliports to be marked with the letters PVT. Since virtually all the heliports in the state are private, the number of heliports with this marking is large. While markings such as this may serve a purpose, they can result in visual clutter and detract from the purpose of a standard marking symbol, decreasing the safety of the facility in the process.

Heliport designers and operators would do well to review their facilities from this perspective and eliminate unnecessary visual clutter in their markings of the final approach and takeoff area (FATO). State aviation authorities would do well to reconsider their heliport marking requirements in light of the results documented in the 1967 report TR 4-67, Development Study for a Helipad Standard Marking Pattern.

8.0 SUMMARY AND PERSPECTIVE.

8.1 Overall Summary. In years past, decisions on heliport design issues have been made on a subjective basis. The FAA's input has reflected the operational experience of the specific individuals involved. The industry's input has also been based on the operational experience of those speaking for industry. At times, the difference in viewpoint has been large and certain issues have been the subject of vigorous debate for many years.

During the 1984 - 1988 time period, the FAA revised the 1977 Heliport Design AC. In discussions with industry on proposed changes, the level of debate intensified. Industry recommended that the FAA "be more objective" in their decision making on heliport design issues. The FAA accepted this advice and initiated a number of research efforts in response. The majority of these efforts are now complete. Thus, judgments can be made on where changes are appropriate and where additional study is required.

The Heliport Design advisory circular should strike a balance between safety and economics. Decisions on the contents of such an AC are not based on technical input alone. Design criteria have economic and political consequences and these issues must be considered. Technically, it is clear that many of the minimum requirements in the 1988 Heliport Design AC are inadequate. Politically and economically, other arguments can be made.

Economic impact is a powerful issue to be considered in proposals to strengthen safety recommendations. The FAA wishes to avoid million dollar "solutions" to thousand dollar problems. At the same time, industry would do itself a disservice if they were to use economic impact as the automatic response to all safety proposals.

Consider the proposal to recommend a wind sock at all heliports. (The 1988 Heliport Design AC only requires a "wind indicator" at private heliports.) The argument has been made that a wind indicator, such as a flag, is less expensive. Close examination raises questions, however, as to whether this cost argument can be supported. Industry sources indicate that a wind sock can be installed for between $100 and $3000 depending on size of the wind sock, height and type of the pole, lighting for night operations, use of guy wires, etc. Thus, the installation costs of a wind sock and a flag of comparable configuration are virtually identical. Technically, however, a wind sock is vastly superior to a flag in terms of safety benefits (better visibility, better information about wind velocity, flags tend to get wrapped around the pole, existing flags are often far removed from the heliport location where one would locate a wind sock, etc.). Cost must certainly be considered in the "cost versus safety" discussion but the cost data must be accurate if the proper balance is to be reached.

In an advisory circular, one sometimes sees the results of the classical "safety versus economics" arguments. Decisions on the minimum requirements for specific design parameters are at times subject to intense lobbying by industry. The resulting advisory circular should be read with this thought in mind. However, with each revision of the advisory circular, the aviation community would do well to revisit the results of R&D studies and to consider whether the balance between technical, economical, and political considerations points to the need for change.

8.2 Transition. An advisory circular is NOT intended to be a mechanism to aid people in justifying what they have been doing in the past. It is intended to be a document that describes standards, recommendations, and guidance for what is recommended now and in the future. An increase of a design standard means that there will be a transition, perhaps a very lengthy transition, until the recommended changes can be made. This is necessary. Otherwise there can be no increase in the safety of heliport design standards.

One should also recognize that an advisory circular is an advisory document, not a regulation. Many heliports do not meet the recommendations of the 1988 Heliport Design advisory circular. Many heliports were built before the 1988 AC or even the 1977 AC were published. Neither AC recommends that older heliports be brought into compliance with the current standards. Thus, it is inappropriate to argue that an increase in the size of a specific recommendation will result in the closing of heliports. It is not the FAA's intent to close heliports due to non-compliance with the current AC.

Both the FAA and knowledgeable individuals in industry have voiced their concerns that some heliports have safety deficiencies. However, no one has done a formal study to determine the percentage of facilities that do not meet the present design standards or the seriousness of their deficiencies. Several suggestions have been made that such a study be done. There would be value in conducting such studies on a state by state or a region by region basis.

One possible approach would be to review each helicopter landing site (heliport/airport/vertiport) in a state or region; to compare each facility with the recommendations in the current Heliport Design AC, the National Fire Protection Association (NFPA) recommendations, and any state/local requirements; to identify deficiencies; and to develop suggestions on how these deficiencies could be eliminated. The deficiencies list could be a non-regulatory way to encourage the improvement of existing heliports.

There is a need for improvement in heliport design standards. Of greater importance, however, is the need to bring public,

private, and hospital heliports into compliance with the current design advisory circular recommendations.

APPENDIX A

REMARKS BY
CONGRESSMAN NORMAN Y. MINETA

To The Annual Meeting of the

AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

MAY 2, 1984

EVERYBODY IS FOR <u>SAFE</u> TRANSPORTATION, BUT WHAT DOES THAT REALLY MEAN? NOTHING IN LIFE IS TOTALLY SAFE. THERE IS <u>SOME</u> DEGREE OF RISK ASSOCIATED WITH EVERYTHING. WHEN WE SAY WE WANT <u>SAFE</u> TRANSPORTATION, WHAT LEVEL OF RISK IS ACCEPTABLE TO US? IN SHORT, HOW SAFE IS SAFE? I REMEMBER A FEW YEARS AGO THAT LANGHORNE BOND TESTIFIED TO THE AVIATION SUBCOMMITTEE THAT ". . . TRAVELING ON A SCHEDULED AIRLINER IS SAFER THAN ALMOST ANYTHING, EVEN THAN STAYING IN BED." THIS PROMPTED A QUESTION AS TO WHETHER MR. BOND HAD IN MIND SOME PARTICULAR PERIL IN BED.

LOOKING HONESTLY AT OUR SOCIETY, I THINK WE HAVE TO SAY THAT THE ANSWER TO THE QUESTION "HOW SAFE IS SAFE?" VARIES WIDELY BY MODE OF TRANSPORTATION. LOOKING AT THE PAST FIVE YEARS, THERE HAS BEEN AN AVERAGE OF 150 FATALITIES PER YEAR IN AIR CARRIER ACCIDENTS. IN THE SAME PERIOD THERE HAVE BEEN AN AVERAGE OF NEARLY 50,000 HIGHWAY DEATHS PER YEAR.

COMPARING THE TWO MODES OF TRANSPORTATION ON A PER PASSENGER MILE BASIS, YOU ARE APPROXIMATELY <u>130 TIMES SAFER PER MILE</u> ON AN AIR CARRIER THAN YOU ARE ON THIS NATION'S HIGHWAYS. THOSE OF US WHO HAVE BEEN AROUND SAFETY STATISTICS LONG ENOUGH EVENTUALLY GET TO THE POINT WHERE WE ARE MORE NERVOUS DRIVING TO THE AIRPORT AND THEN ONCE WE GET THERE AND TAKE OUR SEAT ON THE AIRPLANE WE RELAX AND FEEL MORE SECURE.

BUT MOST AMERICANS HAVE AN EXACTLY OPPOSITE REACTION: THEY JUMP IN THE FAMILY CAR WITH LITTLE OR NO SAFETY CONCERN, BUT THEIR ANXIETY LEVEL GOES UP WHEN THEY GET ABOARD AN AIRPLANE. AS CONTRARY TO THE FACTS AS THOSE FEELINGS MAY BE, THEY ARE WHAT DETERMINES IN OUR SOCIETY HOW-SAFE-IS-SAFE FOR EACH MODE OF TRANSPORTATION.

I WOULD SUGGEST TO YOU THAT 150 FATALITIES PER YEAR FOR AIR CARRIERS AND 50,000 FATALITIES PER YEAR FOR HIGHWAYS IS AN INDICATION OF WHAT OUR SOCIETY CONSIDERS AN ACCEPTABLE LEVEL OF SAFETY FOR EACH OF THESE MODES. NOT <u>ACCEPTABLE</u> IN THE SENSE OF DESIRABLE: NOT <u>ACCEPTABLE</u> IN THE SENSE THAT PEOPLE DON'T MIND THESE FATALITIES AND DON'T WISH THEY WERE LOWER; BUT <u>ACCEPTABLE</u> IN THE SENSE THAT AT THOSE LEVELS MOST AMERICANS ARE WILLING TO JUMP IN THE FAMILY CAR OR TO BOARD AN AIRCRAFT TO GET WHERE THEY WANT TO GO. THEY DO IN FACT <u>ACCEPT</u> THAT LEVEL OF RISK.

IS IT TOO FAR TO SAY THAT OUR SOCIETY <u>ACCEPTS</u> 50,000 HIGHWAY DEATHS PER YEAR? CONSIDER FOR A MOMENT HOW EASY IT WOULD BE FOR US TO DRASTICALLY REDUCE THOSE DEATHS IF WE REALLY WANTED TO. VIRTUALLY ALL CARS ARE EQUIPPED WITH SEAT BELTS, YET ONLY ABOUT 14% OF US BOTHER TO BUCKLE UP. IT IS ESTIMATED THAT ROUGHLY 15,000 AMERICAN LIVES COULD BE SAVED <u>ANNUALLY</u> IF EVERYBODY WOULD JUST BUCKLE THE SEAT BELTS THAT SIT WITHIN THEIR REACH.

CONSIDER MORE SPECIFICALLY THE EFFECT OF MOTOR VEHICLE ACCIDENTS ON CHILDREN AND YOUNG PEOPLE. FOR THE AGE GROUP 1 TO 44 YEARS OLD, MOTOR VEHICLE ACCIDENTS CAUSE MORE DEATHS THAN ANY OTHER CAUSE: MORE THAN CANCER, MORE THAN HEART DISEASE, MORE THAN ANY OTHER DISEASE OR ACCIDENT. THIS IS PARTICULARLY TRUE FOR YOUNG CHILDREN, WHERE AUTOMOBILE ACCIDENTS ALONE ACCOUNT FOR 45% OF ALL CHILDHOOD DEATHS. ON TOP OF THAT, AUTOMOBILE ACCIDENTS ARE THE NUMBER ONE TRAUMATIC CAUSE OF EPILEPSY IN CHILDREN AND ARE A MAJOR CAUSE OF MENTAL RETARDATION AND SPINAL CORD INJURY IN CHILDREN. YET THE MOST ASTONISHING MOTOR VEHICLE STATISTIC IS THAT <u>90%</u> OF ALL CHILD PASSENGER FATALITIES, AND 67% OF THE DISABLING INJURIES TO CHILDREN, COULD BE PREVENTED SIMPLY BY THE PROPER USE OF CHILD SAFETY SEATS.

YET WITH SO PRECIOUS A CARGO AS OUR OWN CHILDREN, AND SO EFFECTIVE A REMEDY AVAILABLE TO US, THE MAJORITY OF US STILL DO NOT BOTHER. WE USE CHILD SAFETY SEATS ONLY ABOUT 40% OF THE TIME, AND WE USE THEM <u>PROPERLY</u> ONLY ABOUT 12% OF THE TIME.

SO WE <u>DO</u> <u>ACCEPT</u> THOSE 50,000 HIGHWAY DEATHS IN THE SENSE THAT REMEDIES ARE READILY AVAILABLE AND WE CHOOSE NOT TO APPLY THEM.

WHAT DOES ALL OF THIS MEAN FOR AVIATION?

IF AIR TRAVEL WERE ONLY 10 TIMES AS SAFE AS THE HIGHWAYS, ALMOST NOBODY WOULD BE WILLING TO FLY. IN FACT, THEY'D DRIVE INSTEAD.

OUR SOCIETY CLEARLY IMPOSES A MUCH HIGHER SAFETY STANDARD ON AVIATION THAN IT DOES ON HIGHWAYS; IN FACT, THE DISCREPANCY BETWEEN THE TWO STANDARDS IS CLEARLY BEYOND THE REALM OF THE RATIONAL. HOW-SAFE-IS-SAFE IS ULTIMATELY A QUESTION OF SOCIAL VALUES, BETTER APPROACHED BY SOCIAL SCIENTISTS OR POLITICAL PHILOSOPHERS, THAN BY ENGINEERS, WHO ARE ENTIRELY TOO RATIONAL. NO RATIONAL RISK ANALYSIS OR COST-BENEFIT ANALYSIS WOULD CONCLUDE THAT THE NEXT INCREMENT OF SAFETY IMPROVEMENT NEEDED IN THIS COUNTRY IS IN AVIATION.

YET THE FACT IS THAT AVIATION <u>HAS</u> TO MEET A MUCH HIGHER SAFETY STANDARD. TO ARGUE THE IRRATIONALITY OF THE DISCREPANCY IN SAFETY STANDARDS, TO ARGUE THAT ANY AVIATION SAFETY PROPOSAL WOULD SAVE ONLY A VERY FEW LIVES, TO ARGUE THAT THERE ARE OTHER AREAS WHERE LESS COST AND EFFORT WOULD SAVE FAR MORE LIVES: ALL THAT IS TRUE BUT IRRELEVANT. AVIATION <u>HAS</u> TO MEET OUR SOCIETY'S HIGHER SAFETY STANDARD FOR AVIATION. ARGUING AGAINST THAT STANDARD IS LIKE ARGUING AGAINST GRAVITY OR AGAINST THE SUN RISING IN THE EAST. THESE THINGS ARE SIMPLY GIVEN. IF AVIATION IS TO THRIVE AND GROW IN OUR SOCIETY IT HAS TO MEET OUR SOCIETY'S STANDARDS, WHATEVER THOSE STANDARDS MIGHT BE.

UNLIKE OUR NATION'S HIGHWAYS, AIR TRAVEL IS SO SAFE THAT THERE ARE NO RELATIVELY LOW COST/LOW EFFORT SOLUTIONS LAYING ABOUT WHICH WOULD SAVE LARGE NUMBERS OF LIVES. WE ARE DOWN TO STRAINING TO ACHIEVE RELATIVELY SMALL INCREMENTS OF SAFETY IMPROVEMENTS.

WHEN YOU CONSIDER THAT THERE ARE ONLY ABOUT 150 AIR CARRIER FATALITIES PER YEAR, AND THAT IN MOST OF THOSE FATAL ACCIDENTS THE AIRCRAFT OR ITS MECHANICAL SYSTEMS WERE NO PART OF THE CAUSE OF THE ACCIDENT, IT BECOMES CLEAR THAT THERE IS NOTHING THAT CAN BE DONE IN THE AREA OF AIRCRAFT DESIGN, MATERIALS, OR PERFORMANCE THAT COULD SAVE MORE THAN A FEW LIVES PER YEAR. THAT IS NOT TO SAY THAT NOTHING SHOULD BE DONE. ON THE CONTRARY, WHAT IT DOES MEAN IS THAT THE ARGUMENT THAT A GIVEN SAFETY PROPOSAL SHOULD NOT BE PURSUED BECAUSE IT WOULD SAVE ONLY A FEW LIVES A YEAR IS AN ARGUMENT FOR NO IMPROVEMENT AT ALL IN AIRCRAFT SAFETY, AND THAT KIND OF STAND-PAT APPROACH IS CLEARLY NOT GOING TO MEET THIS SOCIETY'S SENSE OF WHAT SHOULD BE HAPPENING IN AVIATION SAFETY.

IN A MODE OF TRANSPORTATION WHICH ALREADY HAS SUCH A SUPERLATIVE SAFETY RECORD, ADDITIONAL SAFETY IMPROVEMENTS ARE BOUND TO COME HARD, BUT THEY ARE NOT IMPOSSIBLE. IN AVIATION, WE HAVE A SAFETY SYSTEM WHICH HAS TRADITIONALLY BEEN ORIENTED TOWARD CRASH PREVENTION, AN OBJECTIVE NO ONE WOULD QUARREL WITH. BUT WE HAVE MADE SO MUCH PROGRESS ON THAT FRONT THAT NOW, AS WE SEARCH FOR THOSE INCREASINGLY HARD-TO-FIND EXTRA LIVES THAT COULD BE SAVED, WE NEED TO LOOK MORE IN THE AREA OF CRASH SURVIVABILITY. THE FIRE SAFETY THREAT POSED BY THE URETHANE CUSHIONS IN AIRCRAFT, THE VERY LOW CRASH RESISTANCE CAPABILITY OF AIRCRAFT SEATS AND THEIR FLOOR ATTACHMENTS, PROBLEMS RELATED TO RAPID EGRESS IN A POST-CRASH SETTING, SMOKE DETECTORS IN CLOSED-OFF AREAS SUCH AS LAVATORIES: THESE ARE ALL AREAS WHERE SAFETY REMEDIES ARE AVAILABLE EVEN THOUGH THE ABSOLUTE NUMBER OF LIVES SAVED WOULD, OF COURSE, BE RELATIVELY LOW.

WITH 70% OF ALL AIR CARRIER FATAL ACCIDENT REPORTS LISTING FLIGHT DECK CREW PERFORMANCE AS A CAUSE OR A FACTOR IN THE ACCIDENT, OBVIOUSLY FLIGHT CREW PERFORMANCE HAS THE LARGEST POTENTIAL FOR FURTHER SAFETY IMPROVEMENT. THAT MEANS WORK ON TRAINING, IMPROVED AND POSSIBLY EXPANDED USE OF DRAMATIC ADVANCES IN SIMULATOR TECHNOLOGY, HUMAN ENGINEERING WORK ON CONTROLS AND COCKPIT DESIGN, AND A BETTER UNDERSTANDING OF FLIGHT CREW PERFORMANCE AND INTERACTION. THAT PROCESS HAS TO BEGIN WITH A BETTER UNDERSTANDING OF JUST WHAT IT IS THAT IS THE ROOT CAUSE OF THOSE FLIGHT CREW PROBLEMS. AND THAT UNDERSTANDING BEGINS WITH ACCIDENT INVESTIGATION. THERE IS NO QUESTION THAT THE NATIONAL TRANSPORTATION SAFETY BOARD HAS COME TO REALIZE THE IMPORTANCE OF THIS KIND OF HUMAN FACTORS WORK IN ITS ACCIDENT INVESTIGATIONS. BUT JUST AS IT WAS ABOUT TO IMPROVE ITS CAPABILITY IN THIS AREA, THE REAGAN ADMINISTRATION STEPPED IN WITH A 27% REDUCTION IN BOARD STAFFING DURING FISCAL YEARS

1981 AND 1982. ACCIDENT INVESTIGATION IS THE EYES AND EARS OF SAFETY WORK; IT'S HOW WE KNOW WHAT THE PROBLEMS ARE AND WHAT CAN BE DONE ABOUT THEM. WE ARE WORKING AGAINST THE ADMINISTRATION AT THIS POINT JUST TRYING TO RESTORE HALF THE CUTS IT MADE IN THE N.T.S.B. STAFF, AND ONE OF OUR MAIN PURPOSES IN DOING THAT IS TO TRY TO GET MORE STAFFING IN THE HUMAN FACTORS AREA.

ANOTHER 45% OF ALL AIR CARRIER FATAL ACCIDENT REPORTS LIST WEATHER AS A CAUSE OR A FACTOR IN THE ACCIDENT, AND OF COURSE THAT FIGURE IS MUCH HIGHER FOR GENERAL AVIATION. BUT IT SHOWS AGAIN THAT THERE ARE IMPROVEMENTS THAT COULD BE MADE IN THE DETECTION, UNDERSTANDING, AND TIMELY DISSEMINATION OF WEATHER DATA WHICH COULD SAVE LIVES. PARTICULARLY THE DEVELOPMENT OF DOPPLER RADAR TECHNIQUES TO DETECT CLEAR AIR TURBULENCE AND SHEARS HAS GREAT POTENTIAL. MANY OF THESE CONCEPTS WERE EMBODIED IN NEXRAD AS CALLED FOR IN THE NATIONAL AIRSPACE SYSTEM PLAN. BUT WE'RE DISCOVERING THAT IT IS EASIER TO PUBLISH THE PLAN THAN IT IS TO STICK TO THE ORIGINAL FUNDING PROMISES, AND THERE IS INCREASING CONCERN THAT MANY OF THE N.A.S. PLAN'S BENEFITS WILL BE DEFERRED DUE TO SLOWER-THAN-PROMISED FUNDING.

AND FINALLY, WE SHOULD CONSIDER THE VAST SAFETY REGULATORY SCHEME THAT GOVERNS THE OPERATIONS AND MAINTENANCE OF THE AIR CARRIERS. WE HAVE DEREGULATED THE ECONOMIC DECISION-MAKING OF THE AIRLINES, BUT WE HAVE NOT AND WILL NOT DEREGULATE SAFETY. JUST ABOUT EVERY ASPECT OF THE CARRIERS' OPERATIONS AND MAINTENANCE IS SUBJECT TO THE SAFETY REGULATION OF THE F.A.A., AND THE QUALITY AND EFFECTIVENESS OF THAT REGULATION HAS AT LEAST AS MUCH TO DO WITH SAFE PERFORMANCE IN THIS INDUSTRY AS DO THE ISSUES OF ENGINEERING, DESIGN, AND HARDWARE.

THERE ARE THOSE WHO ARGUE THAT THIS WAS A SAFER INDUSTRY BEFORE ECONOMIC DEREGULATION -- THAT THE COMPETITIVE PRESSURES HAVE FORCED CARRIERS TO CUT COSTS AND THEREFORE CUT SAFETY CORNERS AS WELL.

THE SAFETY STATISTICS ARGUE THE OPPOSITE, HOWEVER. IN THE FIRST FIVE YEARS OF THE 1970'S, THERE WERE AN AVERAGE OF 246 AIR CARRIER FATALITIES PER YEAR. THAT DROPPED TO 150 FATALITIES PER YEAR IN THE MOST RECENT FIVE-YEAR PERIOD UNDER DEREGULATION. COMPARING THE SAME TWO PERIODS IN TERMS OF ACCIDENTS PER AIRCRAFT HOURS FLOWN, THE FATAL ACCIDENT RATE HAS BEEN CUT IN HALF AND THE RATE FOR ALL ACCIDENTS HAS BEEN CUT BY NEARLY 60%. SO THE TREND OF STEADY AND SIGNIFICANT SAFETY IMPROVEMENTS HAS DEFINITELY CONTINUED UNDER ECONOMIC DEREGULATION.

BUT MORE IMPORTANTLY, I THINK THE WHOLE ARGUMENT THAT WE SHOULD RETURN TO THE LESS EFFICIENT DAYS OF ECONOMIC REGULATION IN THE HOPE THAT SOME OF THAT EXCESS FAT ALL THROUGH

THE INDUSTRY MIGHT TRICKLE DOWN TO THE OPERATIONAL SAFETY LEVEL IS JUST PLAIN WRONG. IF SOMETHING IS NECESSARY TO A SAFE OPERATION YOU REQUIRE THAT SOMETHING BY SAFETY REGULATION AND YOU SEND OUT SAFETY INSPECTORS TO MAKE SURE YOU'RE GETTING IT. THAT IS THE MOST EFFECTIVE AND EFFICIENT WAY TO GET SAFE OPERATIONS.

AND THAT IS WHY ONE OF THE MOST SERIOUS POTENTIAL THREATS TO SAFETY IN RECENT YEARS -- THE REAGAN ADMINISTRATION'S DRASTIC REDUCTION OF F.A.A. SAFETY INSPECTORS BY NEARLY ONE-QUARTER IN FISCAL YEARS 1981 THROUGH 1984 -- CAUSED US SO MUCH CONCERN. SAFETY REGULATION IS NO BETTER THAN THE ENFORCEMENT OF THOSE REGULATIONS, AND THOSE ENFORCING THE REGULATIONS WERE BEING STRETCHED WAY TOO THIN TO DO THE JOB EFFECTIVELY. WE URGED SECRETARY DOLE TO RESTORE THE CUT SAFETY INSPECTOR POSITIONS, AND WE WERE PLEASED WHEN SHE RECENTLY ANNOUNCED THAT SHE WOULD DO SO.

IN SUM, AVIATION ACCIDENTS HAVE <u>NOT</u> COME TO SOME IRREDUCIBLE PLATEAU. THERE <u>ARE</u> STEPS WHICH <u>CAN</u> BE TAKEN TO FURTHER IMPROVE SAFETY PERFORMANCE IN THIS INDUSTRY: SUCH STEPS AS IMPROVED CRASH SURVIVABILITY AND FIRE SAFETY, BETTER HUMAN FACTORS WORK, MORE RESOURCES DEVOTED TO ACCIDENT INVESTIGATION, IMPROVED WEATHER REPORTING AND RADARS, AND RESTORATION OF THE AVIATION SAFETY INSPECTOR WORKFORCE. BUT THE INDUSTRY HAS SUCH AN EXCELLENT SAFETY RECORD THAT ANY SAFETY IMPROVEMENT NECESSARILY PRODUCES ONLY RELATIVELY SMALL INCREMENTS OF ADDITIONAL SAFETY.

HOW SAFE IS SAFE? FOR AVIATION OUR SOCIETY BASICALLY HAS A TWO-PART ANSWER:

(1) SAFER THAN FOR OTHER MODES OF TRANSPORTATION, AND BY A WIDE MARGIN, AND
(2) SAFER WITH EACH PASSING YEAR.

AVIATION HAS GROWN IN PART BECAUSE IT HAS SHOWN AN EVER-IMPROVING SAFETY RECORD. AS OUTSTANDING AS ITS SAFETY RECORD NOW IS, OUR SOCIETY EXPECTS THAT SAFETY RECORD TO CONTINUE TO IMPROVE. I THINK IT CAN IMPROVE AND WILL IMPROVE. AVIATION GOT WHERE IT IS TODAY BY MEETING STANDARDS FAR MORE DEMANDING THAN MOST OTHER SEGMENTS OF OUR SOCIETY HAVE TO MEET. I THINK AVIATION WILL CONTINUE TO MEET THOSE EVER HIGHER STANDARDS.

THANK YOU.

APPENDIX B
REEXAMINATION OF TIP CLEARANCE REQUIREMENTS

The 1988 Heliport Design AC requirements for tip clearances are graphically shown in figures B1 through B3. If one were to sum up the conventional wisdom on which these requirements were based, it might be stated as follows:

Conventional Wisdom of Heliport Design Concerning Tip Clearance Requirements Circa 1960

1. Tip clearance requirements are **directly** proportional to rotor diameter of the largest helicopter expected to use a facility.

2. Hover taxiing takes somewhat more space than ground taxiing.

3. Tip clearance requirements are not a function of whether the obstruction is a fixed or movable object.

The 1988 Heliport Design AC reflected tip clearance requirements that had not changed significantly in over three decades. Extensive research has not uncovered any documentation indicating that these requirements were based on any objective test data. Thus, it is presumed that these requirements were originally postulated and accepted on the basis of subjective operational experience.

Some might claim that these requirements have been in place for decades and that industry has not had a problem with facilities designed to these requirements. However, recent accident analysis (FAA/RD-90/8 and FAA/RD-90/9) indicates otherwise. A significant percentage of helicopter accidents at heliports and airports involve collisions with obstructions. With many types of helicopter accidents, the accident rates are improving. However, the rate of helicopter collisions with obstructions during ground maneuvering is not improving. Interviews with industry helicopter pilots (FAA/CT-TN87/54 Vol. 1, and FAA/CT-TN88/30) also indicate the need for greater tip clearances.

Figure B4 has been excerpted from FAA/CT-TN88/30 (page 38, Figure 16) and modified to show the results of a different analysis of these data. This figure shows the pilots' desired tip clearance under tail wind conditions when the obstruction is another aircraft. The 327 pilot responses have been divided into

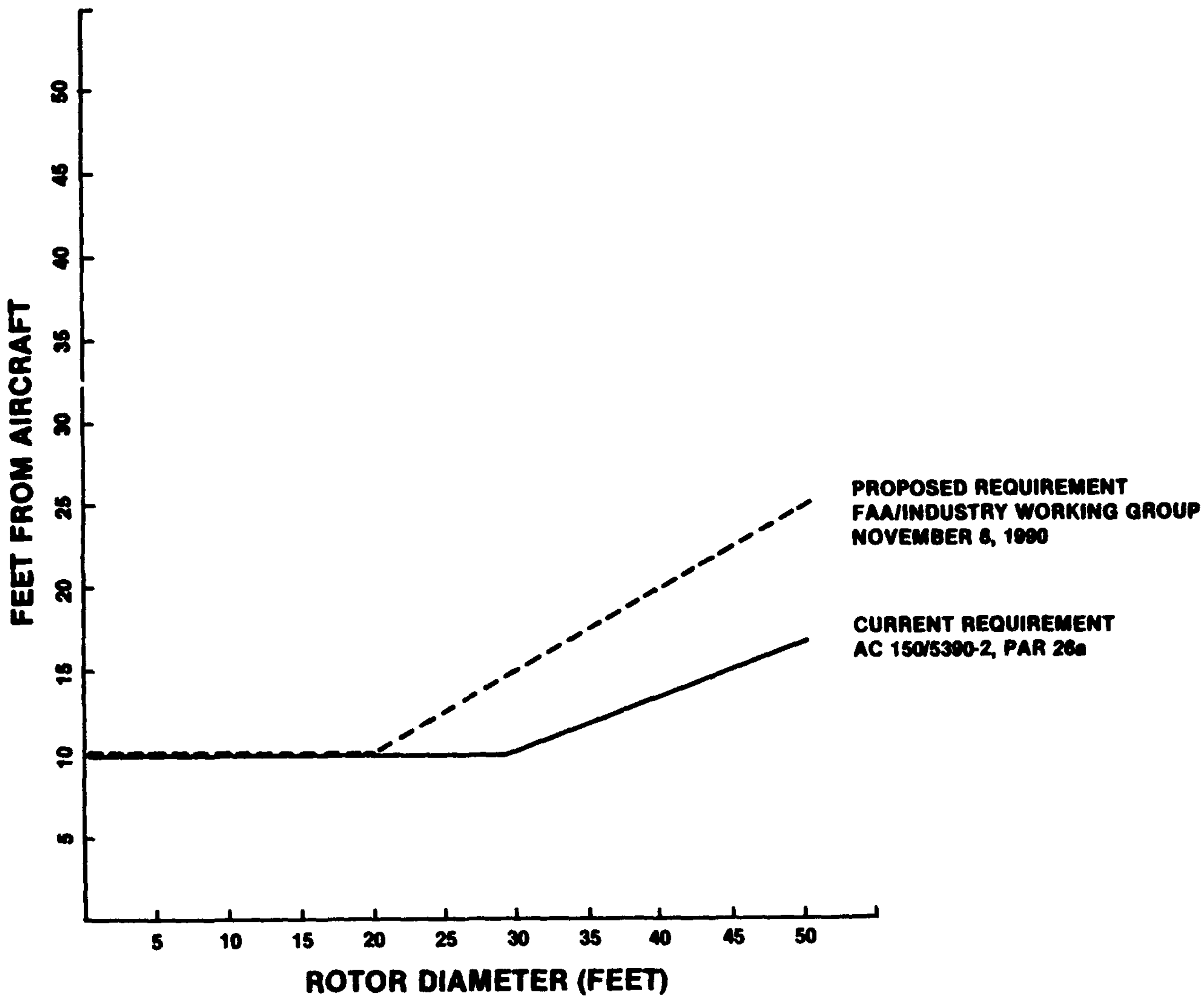


Figure B1. Parking Area Tip Clearances from the TLOF and from Fixed/Movable Objects

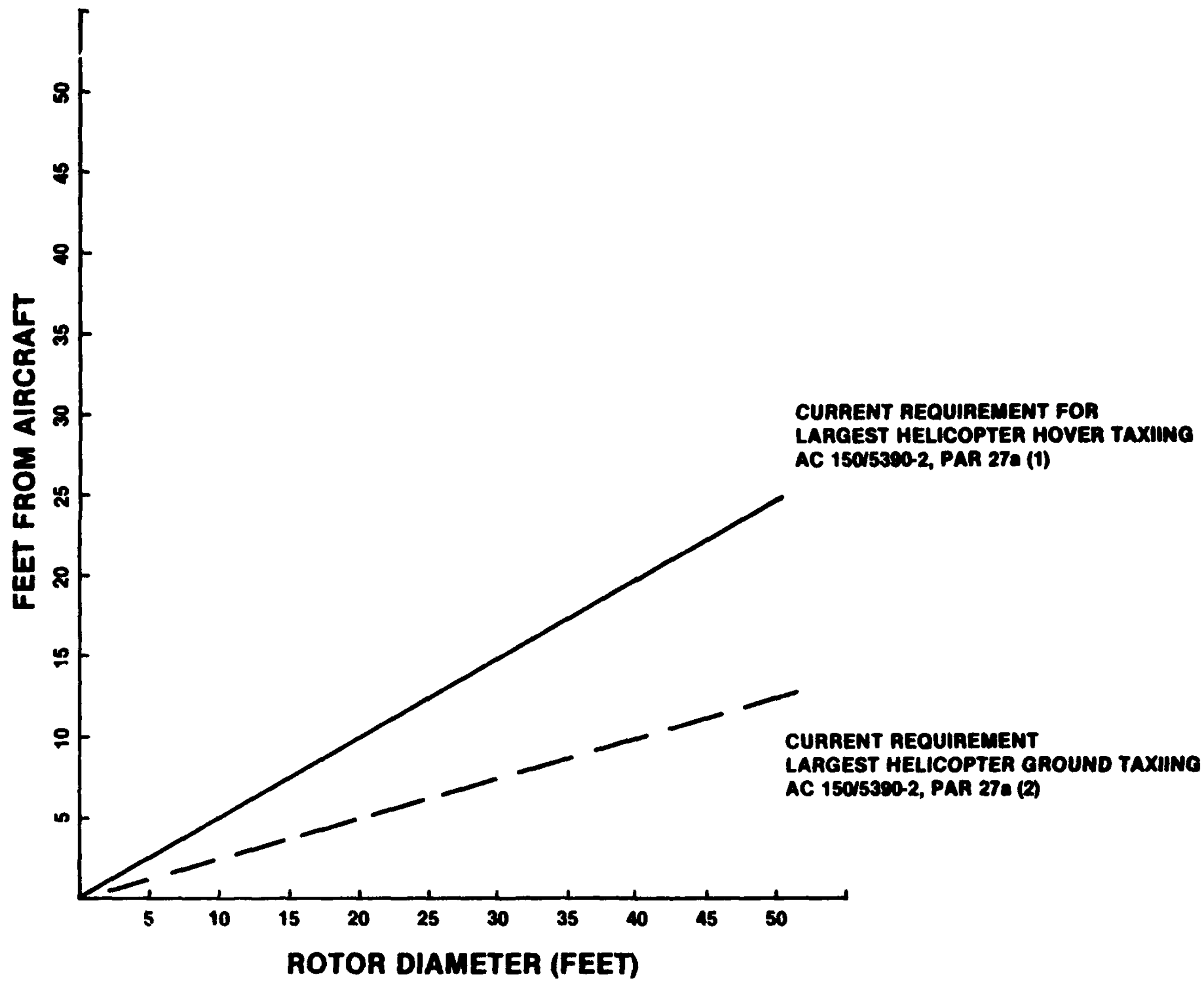


Figure B2. Taxi Route Tip Clearances from the TLOF
and from Fixed/Movable Objects

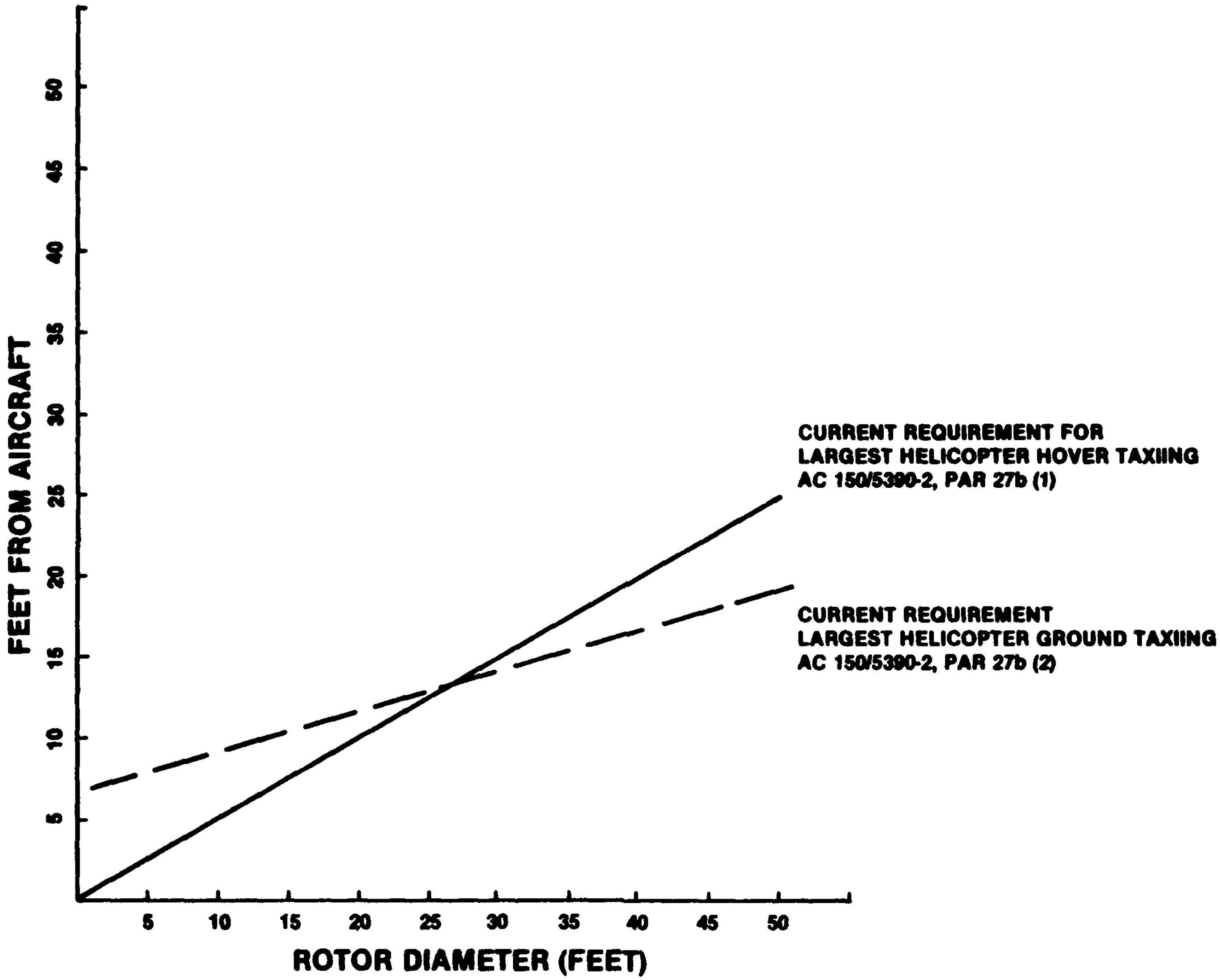


Figure B3. Parallel Taxi Route Tip Clearances from the TLOF and from Fixed/Movable Objects

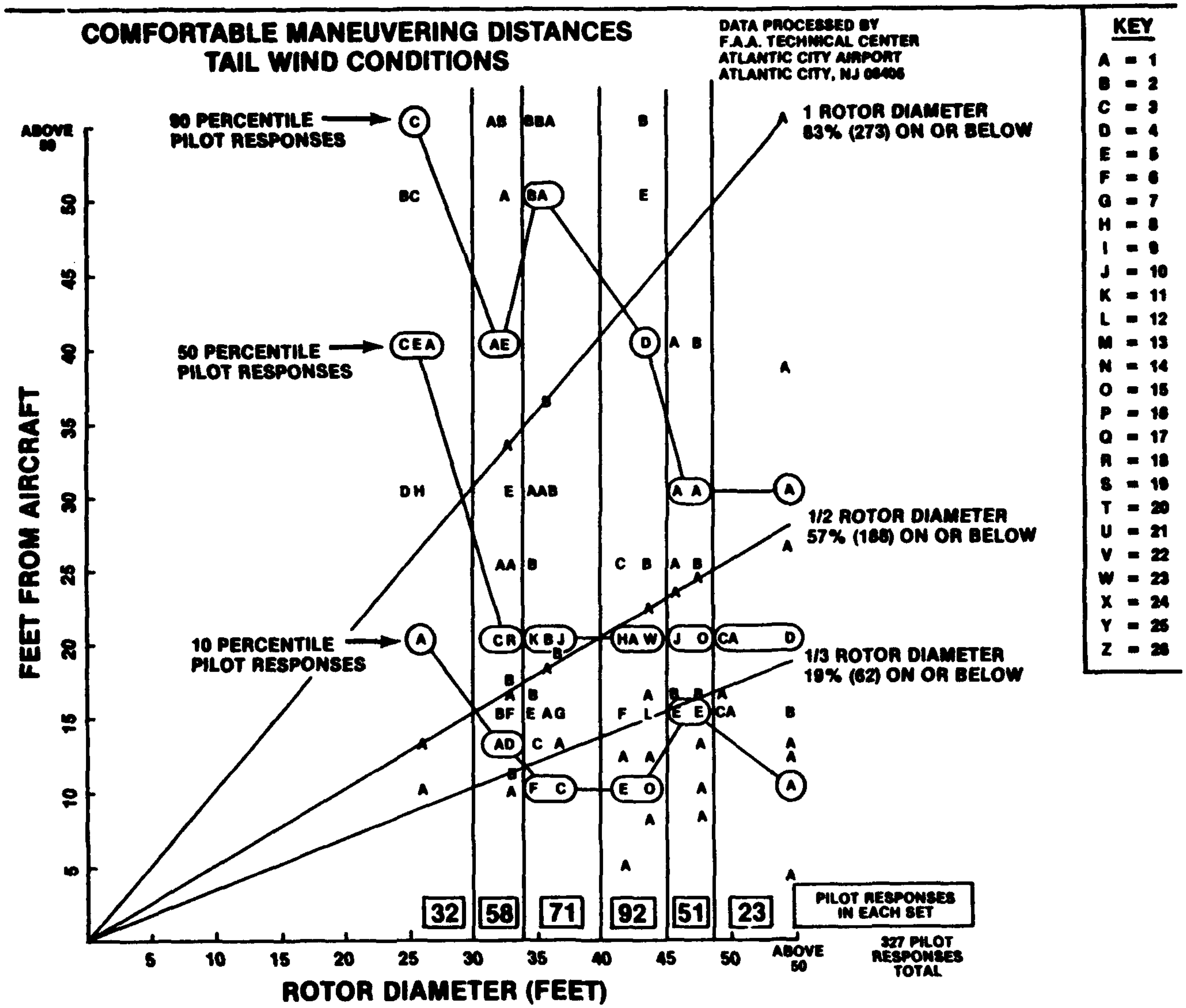


Figure B4. Parking Area Tip Clearances from Movable Objects (Pilot Interviews)

bins as a function of rotor diameter. (These bins are defined by the vertical lines.) Data in each bin have been analyzed in order to find the 10, 50, and 90 percentile points for this group of pilots. (Bear in mind that most of those interviewed were high-time helicopter pilots: 78% had more than 3000 hours helicopter time, 20% had between 500 and 3000 hours.) (Also, analysis of the industry helicopter pilot interview data in FAA/CT-TN87/54 provides similar results to this analysis.) On the basis of this analysis, the following was proposed to industry several years ago as a list of modified list of assumptions for heliport design:

<u>Revised Wisdom of Heliport Design</u>
<u>Concerning Tip Clearance Requirements</u>
<u>Circa 1992</u>

1. Proportional to their rotor diameters, helicopters with small rotor diameters require more tip clearance than large helicopters. (Small helicopters typically have skids requiring that they hover taxi rather than ground taxi. This, coupled with the fact that these aircraft are light, makes pilots aware that they are more likely to be blown around by gusting winds. In addition, the pilot typically sits lower in a small helicopter. This may make it more difficult to judge tip clearances. Finally, low time helicopter pilots typically fly smaller helicopters. Design criteria should account for their limited experience.)

2. Up to a certain point, tip clearance requirements are **indirectly** proportional to rotor diameter ranging from a requirement for a tip clearance of 30 to 50 feet (based on the **90 percentile of pilots interviewed**).

3. For helicopters with a rotor diameter larger than 30 feet, the **median pilot** wants 20 feet tip clearance **regardless of rotor diameter.**

4. Hover taxiing requires **significantly** more space than ground taxiing.

5. Pilots express a need for somewhat larger tip clearances when the obstruction is a movable object (such as another helicopter or an airplane) rather than a fixed object.

6. **Nighttime operations require about 25 percent additional tip clearances (over and above what is discussed in items 1 through 5 above) to compensate for the deterioration of visual cues in low ambient lighting.** (Results of nighttime ground maneuvering testing are discussed in section 2.2.5.)

Additional testing has been done since this "revised wisdom" was proposed and discussed in meetings of the FAA/Industry Heliport Design Working Group. This effort is documented in report FAA/CT-TN93/6, Combined 1991 and 1992 Robinson - 22B (R-22) Parking Test Results.

When the subject pilots were asked to park with an unspecified "safe" rotor tip clearance from another aircraft or from a ground marking, actual tip clearances varied from 1.51 to 23.64 feet with an average of 11.0 feet. When the subject pilots were asked to park with a rotor tip clearance of 10 feet, actual tip clearances varied from 2.88 to 25.94 feet with an average of 14.5 feet. During the various tests, pilot perception errors (actual tip clearance minus the pilot's estimate of the tip clearance) were as large as 17 feet.

One should realise that these subject pilots were aware of the analysis of Appendix B (Specifically that the 50 percentile pilot wanted 40 feet of tip clearance when flying an R-22.). Discussion has raised a concern that a number of the subject pilots may have been motivated to perform in a way that support the tip clearance requirements of the 1988 Heliport Design AC (10 feet tip clearance for an R-22), thereby disproving the need for a 40 foot tip clearance when hovering an R-22.

The results of FAA/CT-TN93/6 do lead one to conclude that a 40 foot tip clearance would be more than the minimum requirement. However, FAA/CT-TN93/6 also shows conclusively that a 10 foot tip clearance requirement is inadequate for an R-22. Rather, the results point to a minimum requirement of about 20 - 25 feet. This is just slightly larger than the 20 feet tip clearance desired by the 50 percentile pilot in rotorcraft with rotor diameters of 30 feet or larger (see Appendix B, figure 4). However, it is considerably smaller than 40 feet tip clearance desired by the 50 percentile pilot in rotorcraft with rotor diameters of 25 feet.

In summary, it appears the the "revised wisdom of heliport design concerning tip clearance requirements (circa 1992)" must be further refined as a result of additional flight testing. Thus, the following refined list is now proposed as a statement of assumptions for helicopter landing site (heliport/airport/vertiport) design:

Further Revised Wisdom of Heliport/Airport/Vertiport Design Concerning Tip Clearance Requirements Circa 1994

1. Tip clearance requirements are **not directly proportional** to rotor diameter. Rather, the tip clearance requirement is relatively constant as a function of rotor diameter:

    a. For helicopters with a rotor diameter of 25 feet, a tip clearance of 20 - 25 feet is appropriate.

    b. For helicopters with a rotor diameter of 30 to 50 feet, the median pilot wants 20 feet tip clearance regardless of rotor diameter.

    c. For helicopters with a rotor diameter of more than 50 feet, a tip clearance of one half rotor diameter is recommended.

2. Hover taxiing requires significantly more space than ground taxiing.

3. Pilots express a need for somewhat larger tip clearances when the obstruction is a movable object (such as another helicopter) rather than a fixed object.

4. Nighttime operations require about 25 percent additional tip clearances to compensate for the deterioration of visual cues in low ambient lighting. (Results of nighttime ground maneuvering testing are discussed in section 2.2.5.)

APPENDIX C. VMC DISTRIBUTION ANALYSIS

Several years ago, the FAA started a flight measurement project to examine the issue of minimum required VFR heliport airspace from a perspective of pilot performance. Test data were collected objectively in a manner similar to what is done to define the minimum airspace required for a precision approach. Heliport approach and departure flight profiles were recorded using a variety of subject pilots flying three different helicopters: a Hughes OH-6, a Sikorsky S-76, and a Bell UH-1. A total of 1217 data runs (approaches or departures) were completed. These included 239 runs with the OH-6, 468 runs with the S-76, and 510 runs with the UH-1. (This topic was discussed in section 2.1.1.1.

A detailed statistical analysis of the VFR heliport approach and departure data is documented in report FAA/CT-TN89/67, Analysis of Distributions of Visual Meteorological Conditions (VMC) Heliport Data. With regard to airspace consumption in the lateral plane, the results of FAA/CT-TN89/67 were shown in figures 1 and 2 of section 2.1.1.1. These figures show the six sigma distribution lateral limits for the originally assumed Gaussian distribution, the six sigma distribution lateral limits for the actual Beta/Gamma distribution, and the current lateral limits of the 8 to 1 approach/departure surface defined in the Code of Federal Regulations (CFR) Title 14, Federal Aviation Regulation (FAR) Part 77. Figures 1 and 2 of section 2.1.1.1 are each comprised of three figures that have been photographically reduced to fit them on one page. These six figures are shown full size in figures C1 through C6 of this Appendix.

Figure C1.

VMC DISTRIBUTION ANALYSIS — ALL AIRCRAFT DATA
7 DEGREE STRAIGHT IN APPROACHES — CROSSTRACK POSITION VS. BIN RANGE

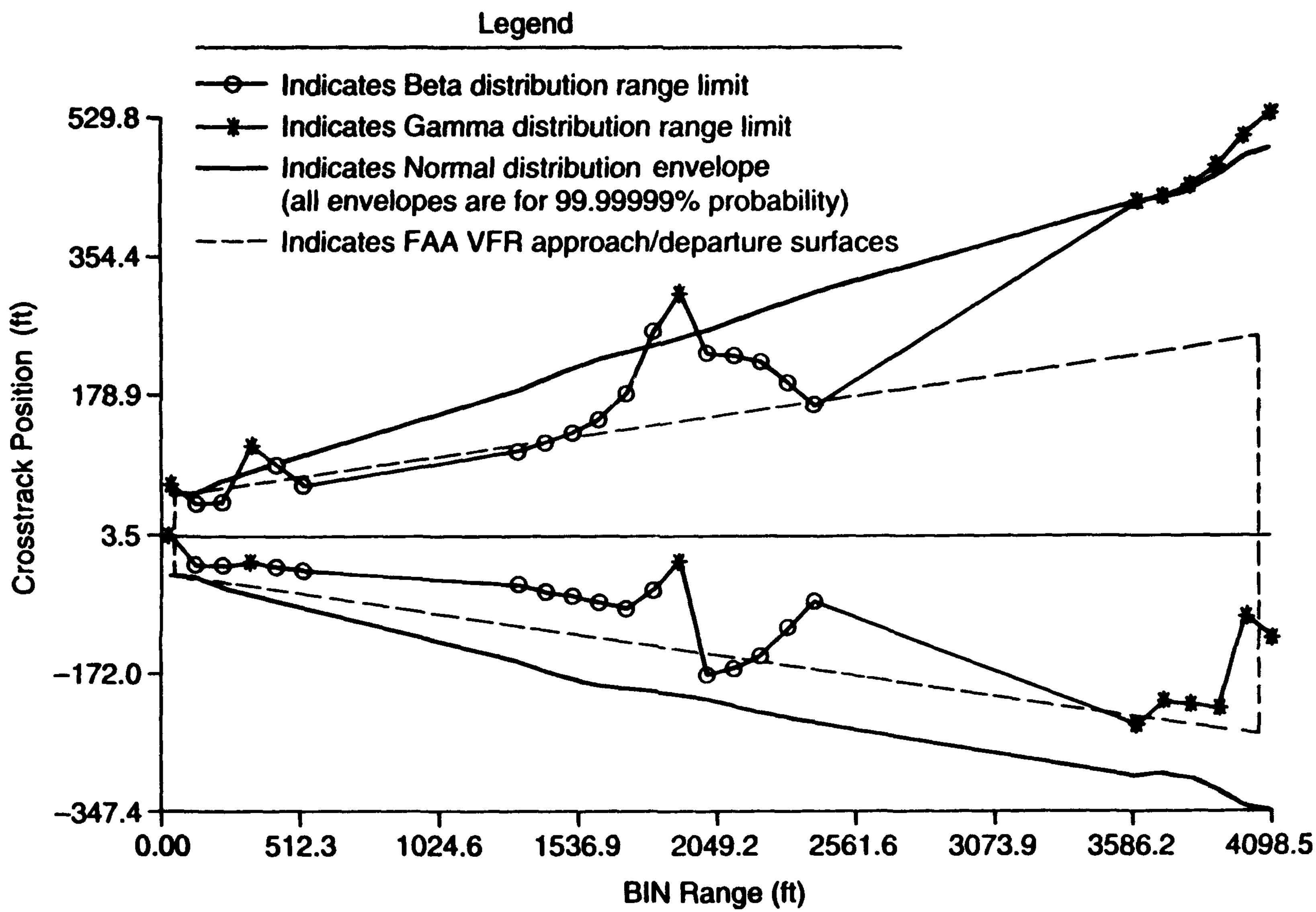


Figure C2.

VMC DISTRIBUTION ANALYSIS — ALL AIRCRAFT DATA
8 DEGREE STRAIGHT IN APPROACHES — CROSSTRACK POSITION VS. BIN RANGE

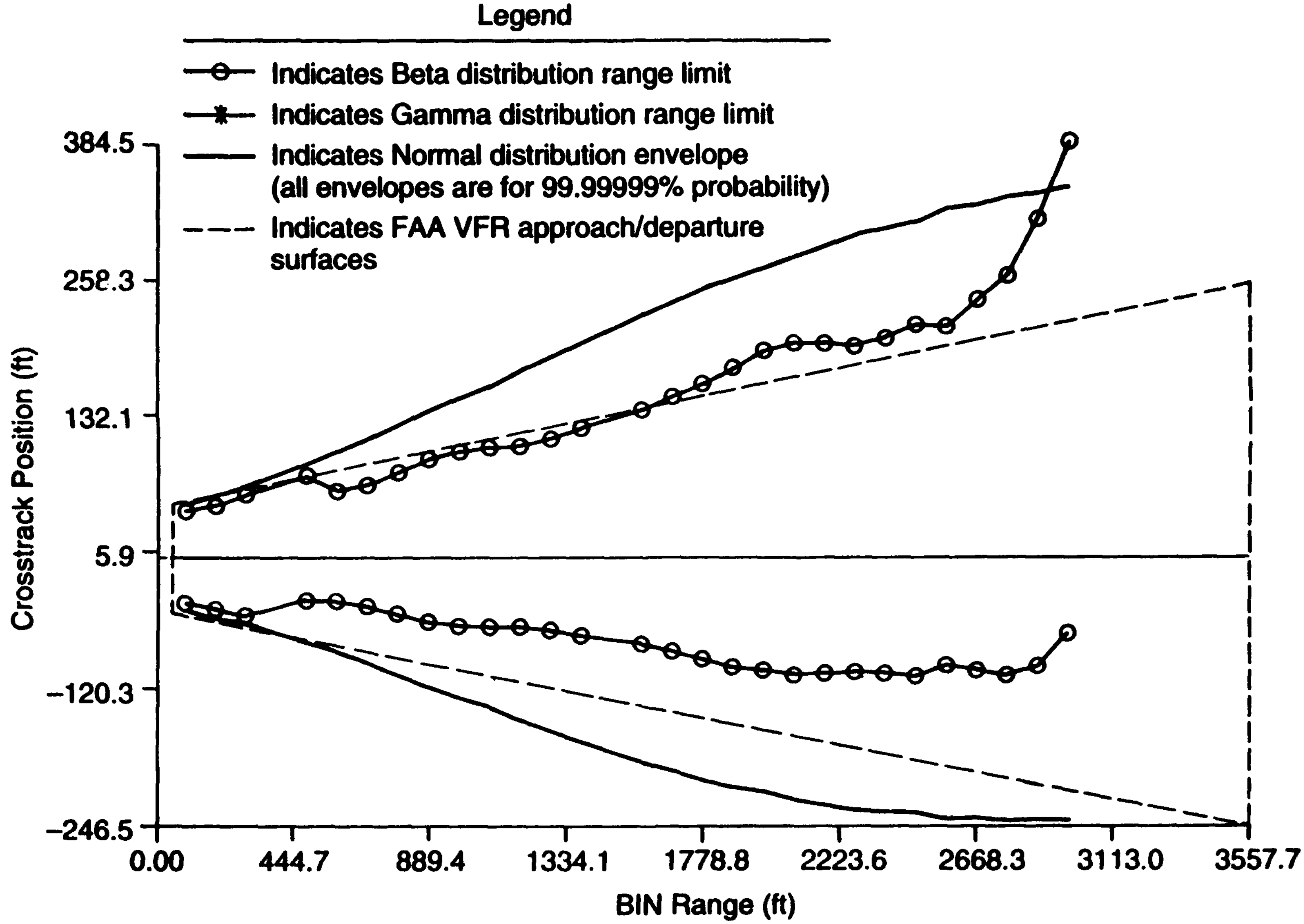


Figure C3.
VMC DISTRIBUTION ANALYSIS — ALL AIRCRAFT DATA
10 DEGREE STRAIGHT IN APPROACHES — CROSSTRACK POSITION VS. BIN RANGE

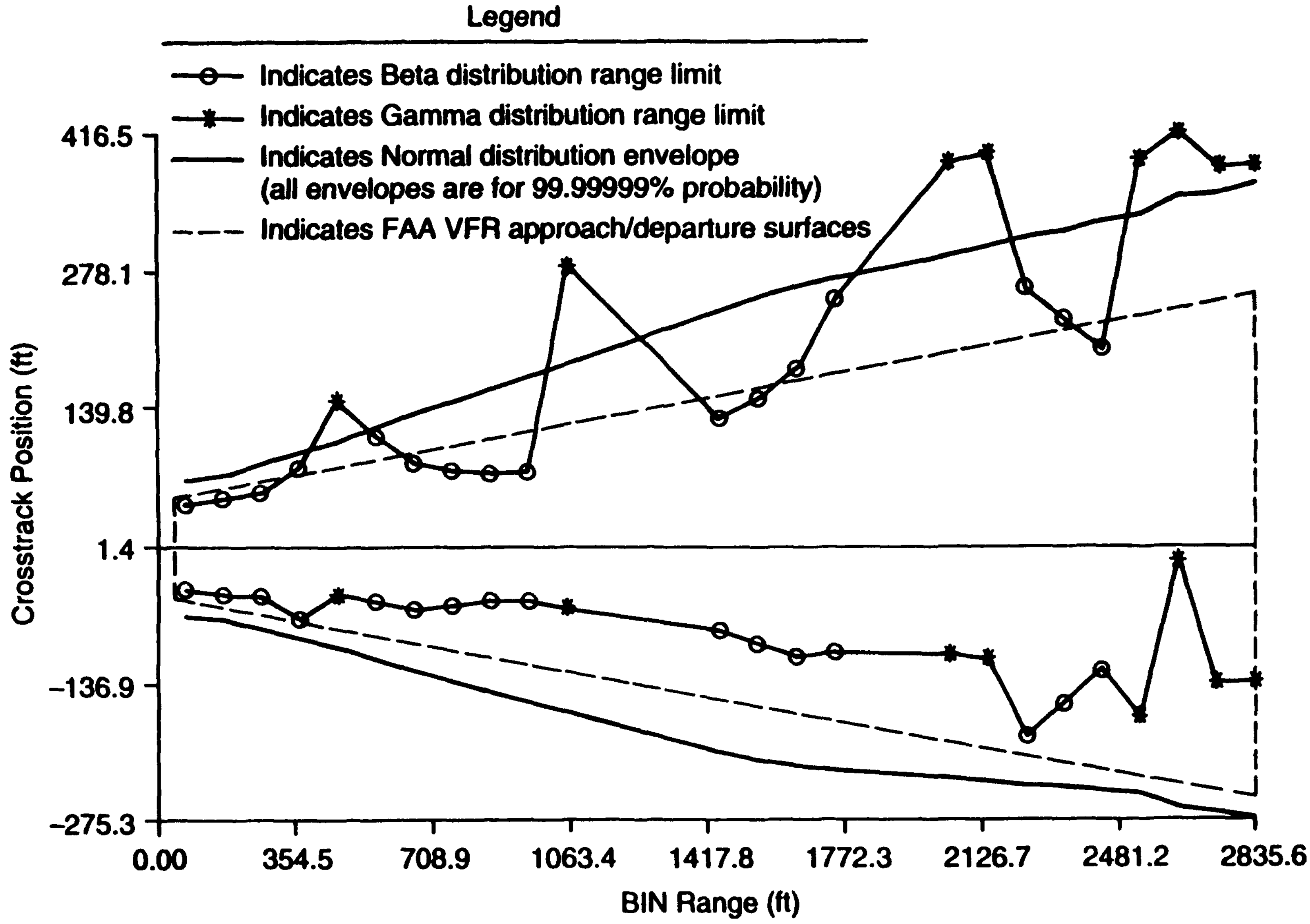


Figure C4.
VMC DISTRIBUTION ANALYSIS — ALL AIRCRAFT DATA
7 DEGREE STRAIGHT OUT DEPARTURES — CROSSTRACK POSITION VS. BIN RANGE

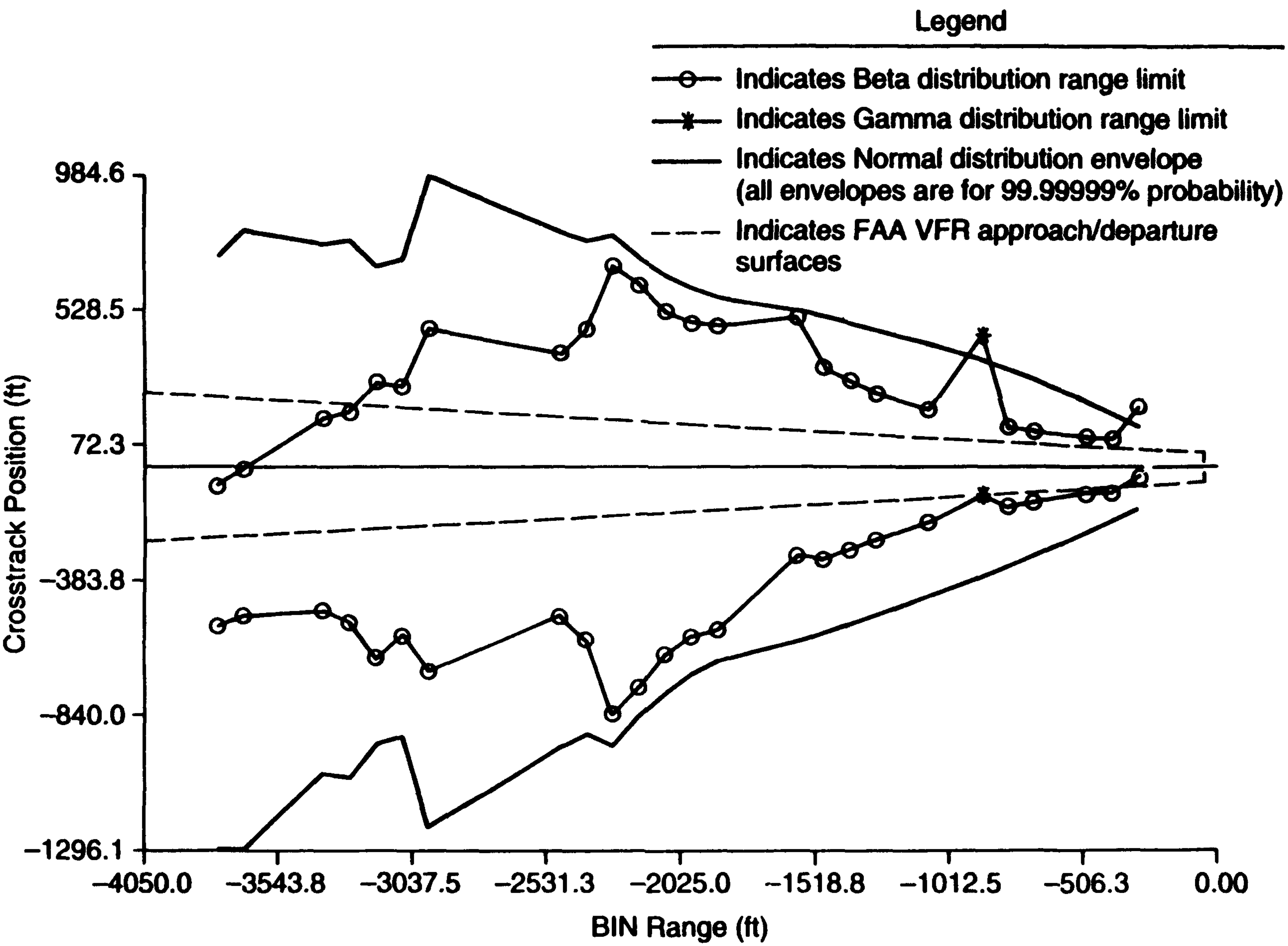


Figure C5.

VMC DISTRIBUTION ANALYSIS — ALL AIRCRAFT DATA
10 DEGREE STRAIGHT OUT DEPARTURES — CROSSTRACK POSITION VS. BIN RANGE

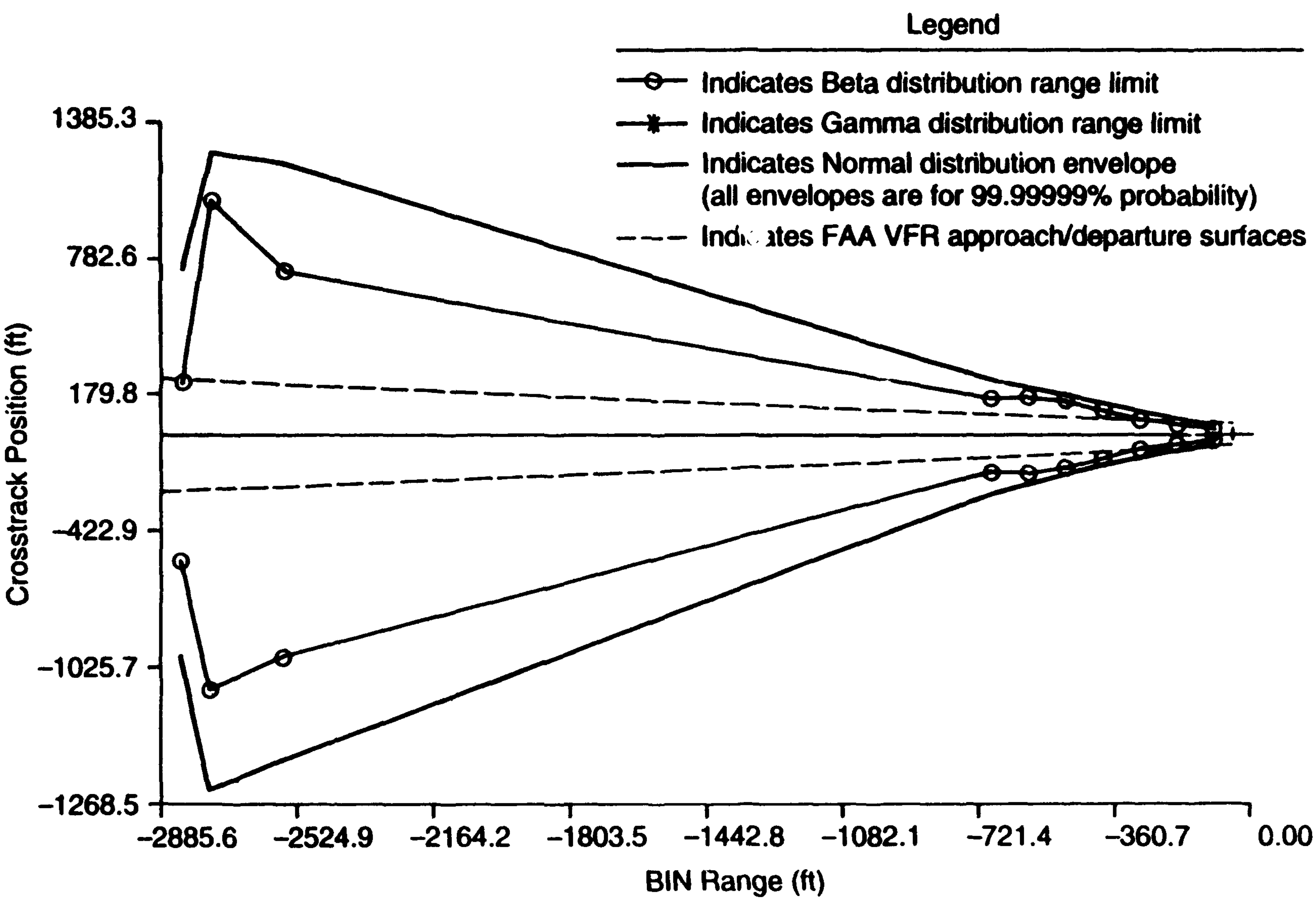
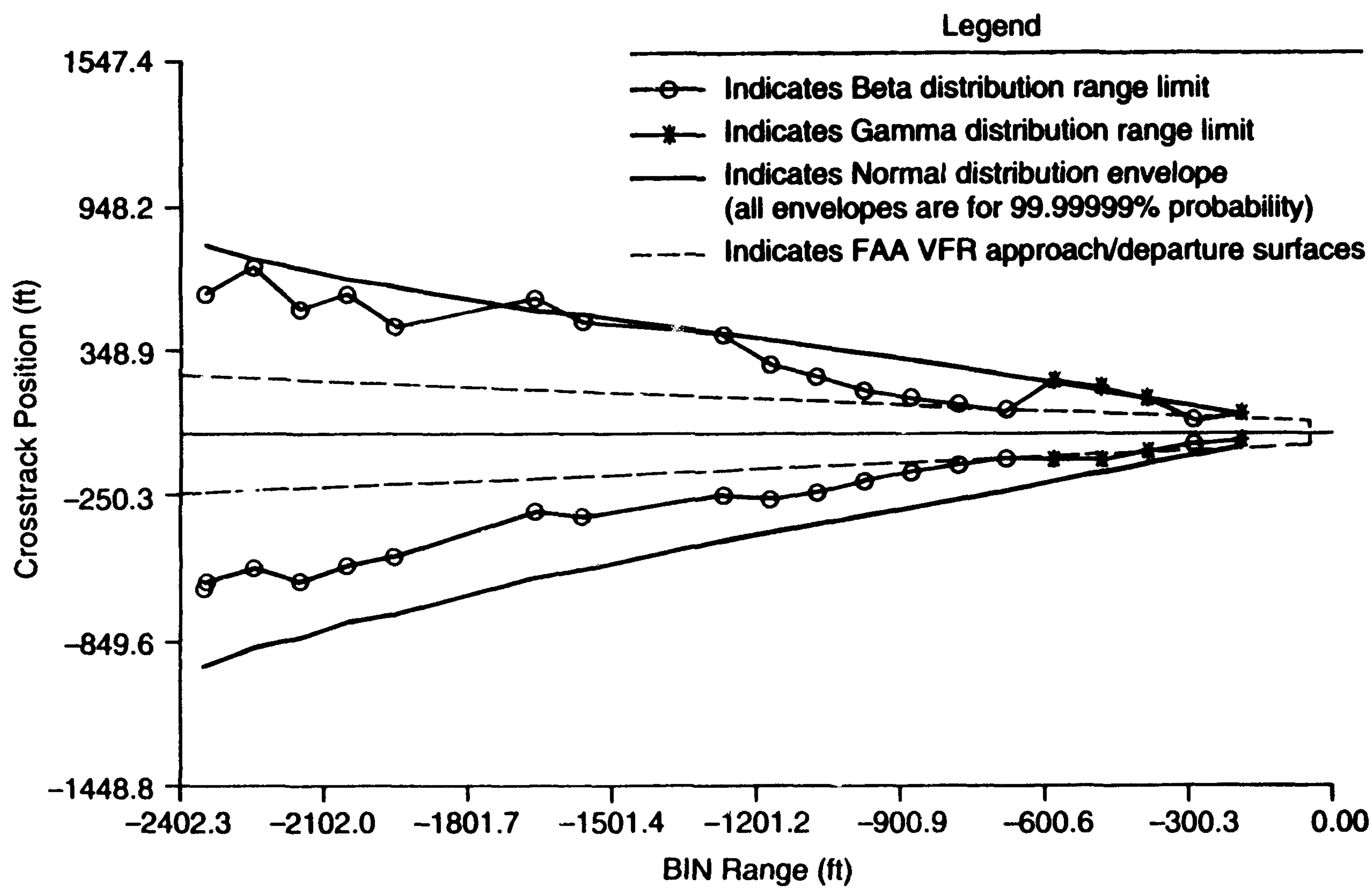


Figure C6.

VMC DISTRIBUTION ANALYSIS — ALL AIRCRAFT DATA
12 DEGREE STRAIGHT OUT DEPARTURES — CROSSTRACK POSITION VS. BIN RANGE



APPENDIX D. ACRONYMS

AIAA	American Institute of Aeronautics and Astronautics
AIP	Airport Improvement Program
AC	advisory circular
AGL	above ground level
AHS	American Helicopter Society
AWOS	automated weather observing system
CFR	Code of Federal Regulations
CL-84	Canadair tiltwing
CTR	Civil tiltrotor
CTR-22A/B	Civil tiltrotor - 31 passengers, V-22 minimum change
CTR-22C	Civil tiltrotor - 39 passenger, V-22 derivative
CTR-22D	Civil tiltrotor - 52 passenger, V-22 derivative
CTR-800	Civil tiltrotor - 8 passenger, high-wing design
CTR-1900	Civil tiltrotor - 19 passenger, low-wing design
CTR-7500	Civil tiltrotor - 75 passenger, low-wing design
DH	decision height
EMS	emergency medical service
EUROFAR	European Future Advanced Rotorcraft
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FATO	final approach and takeoff area
GA	general aviation
GPS	global positioning system
HAI	Helicopter Association International
HALS	heliport approach light system
HNM	helicopter noise model
H-V	height/velocity
IFR	instrument flight rules
ILS	instrument landing system
IMC	instrument meteorological conditions
km	kilometer
KV	kilovolt
LA	Louisiana
MLS	microwave landing system
MRI	magnetic resonance imager
NJ	New Jersey
NFPA	National Fire Protection Association
NTIS	National Technical Information Service
NTSB	National Transportation Safety Board
NY	New York
OEI	one engine inoperative
OH-6	Hughes helicopter
R&D	research and development
R-22	Robinson helicopter
SMES	superconducting magnetic energy storage unit
S-76	Sikorsky helicopter
TERPS	terminal instrument procedures
TLOF	touchdown and lift-off area
TLOS	target level of safety
TW-68	tiltwing being developed by Ishida Aerospace Research

UH-1	Bell military aircraft
UH-1H	Bell military aircraft - H model
USA	United States of America
VFR	visual flight rules
VMC	visual meteorological conditions
VTOL	vertical takeoff and landing
V-22	military tiltrotor
XV-15	experimental tiltrotor